APPLETONS' HOME READING BOOKS

NATURE-STUDY READERS

·III·

HAROLD'S QUESTS

TROEGER

Appletons' Home Reading Books

EDITED BY

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UNITED STATES COMMISSIONER OF EDUCATION

DIVISION I

NATURAL HISTORY

APPLETONS' HOME READING BOOKS

NATURE-STUDY READERS

BY JOHN W. TROEGER

III

HAROLD'S QUESTS

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JOHN W. TROEGER, A. M., B. S.

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EDITOR'S PREFACE.

This series of books is intended to supply what is called supplementary reading for pupils who have been two years or more at school. The first book will, indeed, be found useful even for pupils that are beginning their second year's work at school. The sentences are short and the words are simple. The child in his third year may take home the first book, Harold's Discoveries, read and re-read it at leisure. He will attain facility in recognizing in a printed form words that he already knows by sound.

The first work of the child in the school is to learn to recognize the printed forms of words that are familiar to him by ear. These words constitute what is called the colloquial vocabulary. They are words that he has come to know from having heard them used by the members of his family and by his playmates. He uses these words himself with considerable skill, but what he knows by ear he does not yet know by sight. It will require many weeks, many months even, of constant effort at reading the printed page to bring him to the point where the sight of the written word brings up as much to his mind as the sound of the spoken word. But patience and practice will by and by make the printed word far more suggestive than the spoken word, as every scholar may testify.

In order to hasten the growth of this familiarity with the printed word it has been found necessary to reinforce the reading in the school by supplementary reading at home. Books of the same grade of difficulty with the reader used in school are accordingly provided for the pupil. They must be so interesting to him that he will read them at home, using his time before and after school, and even his holidays, for the purpose.

But this matter of familiarizing the child with the printed word is only one half of the object aimed at by the supplementary home reading. He should read that which interests him. He should read that which will increase his power of making deeper studies. Moreover, what he reads should correct his habits of observation. Step by step he should be initiated into the scientific method. Too many elementary books fail to teach the scientific method, because they do no more than point out in an unsystematic way those features of the object that the untutored senses of the pupil would discover at first glance. It is not useful to tell the child to observe a piece of chalk and see that it is white, more or less friable, and that it makes a mark on a fence or a wall. Scientific observation goes immediately behind the facts which lie obvious to a superficial investigation. Above all, it directs attention to such features of the object as exercise a determining or controlling influence on the environment. It directs attention to the features that have a causal influence in making the object what it is, and in extending its effects to other objects.

Science discovers the causal relations of objects and their reciprocal action on one another.

After the child has learned how to observe what is essential in one class of objects he is in a measure fitted to observe for himself all objects that resemble this class. After he has learned how to observe the seeds of the milkweed, he is partially prepared to observe the seeds of the dandelion, the burdock, and the thistle. After he has learned how to observe the oak, he has learned something of the method of observing the birch, the elm, and the pine. A study of the apple aids his power of observing the cranberry and the cherry. A study of the budding of the willow enables him to understand the budding of the lilac, and a study of the germination of beans to understand that of peas and lentils.

The teacher is liable to err in undertaking to carry the investigation of one province of Nature too far, at the expense of neglecting a similar investigation in other kingdoms of Nature. The books of this series discuss various subjects in botany and in animal life; not only these, but they start investigations in physics. The course is a spiral one, as it ought to be in the elementary school. Even in his first year the child ought to learn something regarding the methods of observation in each of the three great realms of Nature—first, the realm of elements treated of in the science of physics or natural philosophy; second, the realm of botany, treating of the various forms of the plant; and, third, the realm of animal life. Each of these realms of Nature is to be taken up again in the second book, and still again in later books of the series. With the growing power of the child to think and use scientific method he will expect and demand new scientific vistas. These will be furnished one by one in more advanced books.

The teacher of a school will know how to obtain a small sum of money to invest in supplementary reading. In a well-graded school of four hundred pupils ten books of each number are sufficient, these ten books to be loaned the first week to the best pupils in one of the rooms, the next week to a second ten pupils. On Monday afternoon a discussion should be held over the topics of interest to the pupils who have read the book the week before. The pupils who have not yet read the book will become interested and await with eagerness their turn for the loan of the desired volume. Another ten books of a higher grade may be used in the same way in a room containing more advanced pupils. The advantage of this supplementary reading device is not limited to the fact that the pupils of the school read the books at home and reinforce the progress which they make at school by reading in the regular readers. It is another advantage of great importance that the older pupils who have left school, and even the parents avail themselves of the opportunity and read the book thus brought into the house. Thus begins the continuous education that lasts through life, namely, the education by means of the public library.

WILLIAM T. HARRIS.

WASHINGTON, D. C., *April 4, 1898.*

PREFACE.

It has been my aim in this book to present reading matter that shall be worth the child's time to read, and to put it in such a form that it may engage his mind and induce him to "forage beyond the book."

The subject-matter is taken from the common things in nature which children are most likely to meet and find interesting. Animals and plants, their development and their habits, always interest, but the child needs hints and questions to direct him in his seeing and thinking. He needs clews more than facts, wisdom rather than knowledge.

Children never tire of rambles in the forest or boat rides on the river; and, if directed and aided in their observations, as most of them must be, they will find a field for thought that is not only truly refreshing but highly educative. The section on physics is added for the winter hours because of its importance and interest to the children. On every hand they come in contact with these phenomena. If they make a beginning in seeking answers to questions about the life and forces that surround them, they will be acquiring a habit that will make thinking men and women of them. Space permits only the most elementary facts, but it is hoped enough is given to open the mind in this direction—a new field for discovery to the beginner.

It is admitted that nature study is not science, but it should be the first step in the study of science and the best kind of training for it. The subjects herein treated are brought into connected relation, and the first steps of classification suggested. Scientific terms have been sparingly introduced, and then only after their use and meaning have been understood.

The plan adopted in the preceding volumes has been continued—that is, the statements are generally in the first person; the subjects previously taken up are here further expanded and new ones added; the imagination is to be stimulated by the contemplation of facts and forces, not by fanciful nature myths and sentimental personifications. The facts and phenomena of nature have interest enough for the child. If he is taught the unreal and imaginary he will find it a difficult task to confine himself to facts—an altogether too prevalent habit. "Train up a child in the way he should go, and even when he is old he will not depart from it."

JOHN W. TROEGER:

LA GRANGE, ILLINOIS, *August, 1899.*

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HAROLD'S QUESTS.

THE GLADNESS OF NATURE.

Is this a time to be cloudy and sad,
  When our mother Nature laughs around;
When even the deep-blue heavens look glad,
  And gladness breathes from the blossoming ground?

There are notes of joy from the hang-bird and wren,
  And the gossip of swallows through all the sky;
The ground squirrel gayly chirps by his den,
  And the wilding bee hums merrily by.

The clouds are at play in the azure space,
  And their shadows at play on the bright-green vale,
And here they stretch to the frolic chase,
  And there they roll on the easy gale.

There's a dance of leaves in that aspen bower,
  There's a titter of winds in that beechen tree,
There's a smile on the fruit and a smile on the flower,
  And a laugh from the brook that runs to the sea.

And look at the broad-faced sun, how he smiles
  On the dewy earth that smiles in his ray,
On the leaping waters and gay young isles!
  Ay, look, and he'll smile thy gloom away.

BRYANT.

THE GRASSHOPPER.

"SEE this large hay horse!" said a man to me in German one day, as I approached him in the fields. He had a large grasshopper in his hand.

Meadow grasshopper.

I told him it was a grasshopper, and asked him why he called it a hay horse.

He replied: "We call him grasshopper too, sometimes, but more often, hay horse. He looks like a horse pulling a heavy load, and he can always be found in hayfields."

I had to admit that I could see some resemblance to a horse, as he had said.

Red-legged locust.

As you will see in the pictures, there are two kinds of grasshoppers. One kind has short, straight antennæ, and the other has long, curved ones. There is also some difference in their wings and legs and the shape of their abdomen.

Those that have long antennæ are called grasshoppers, and the others are usually called locusts, but there is much confusion about the names. Some even call the cicada a locust.

I have seen large green grasshoppers in the fields. They look so much like the grass that it's

Cone-headed grasshopper.

hard to find them. There are others that are as gray as the dusty road, where they like to sun themselves. When open their wings show black bars and dull-red spots.

Can you think of any reason why the grasshopper that lives in the grass is green and the one that lives in the road is gray? Do you think the green grasshopper is green because he lives in the grass, or does he live in the grass because he is green? Do you think the gray grasshopper feels safer from his enemies when he sits in the dusty road than when he sits in the grass? Do you remember how much the meadow lark looks like the dry grass in which her nest is? Perhaps you have seen snakes which are green marked with black, so that they look like the grass with shadows crossing it. If we have sharp eyes we may see many other creatures which seem to take on the color of their surroundings. What do you think is the cause of this?

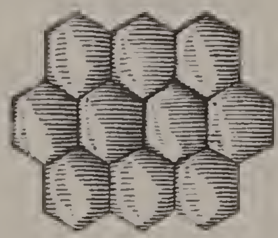
All grasshoppers have the body in three parts: a clumsy head, a thick thorax, and an abdomen which is closely joined to the thorax. The head has two antennæ, large eyes and jaws. To the thorax are attached the six legs. The hind pair is long and strong. Can you tell why?

How quickly he jumps! and he needs to. He has many enemies, such as birds and small insect-eating animals. If the bobolink's sharp eyes should spy him in the grass he would scarcely be able to get away, even with his long legs.

If a man had as much strength in his legs in proportion to his size as has the grasshopper, he could easily jump over the highest building.

A grasshopper's eyes are worth noticing. I find two kinds in his head: a pair of large ones, and smaller ones besides.

The large ones are made of many little eyes, as you can see with a magnifying glass. The small ones seem to be single. By looking sharply I found three of these. Where do you suppose the third one is? I think I will let you find it. I'm sure you'll be surprised when you do.



Part of compound eye.

I've often taken the grasshopper in my hand, and then he spits out a dark-brown fluid, which the children call tobacco juice. Has he the bad habit of chewing tobacco? No, no, for I believe he never goes near tobacco.

Why does he give out this juice? Is it a means of defense? It does not have a bad odor. I wonder if it is poisonous to some of his enemies.

Some of the grasshopper's enemies are fond of her eggs and destroy thousands of them every year. For this reason she does everything she can to protect the eggs.

When she wishes to lay them she digs a hole in the ground with her egg-layer and puts the eggs in it. She drops a sticky fluid over them, which hardens, and forms a case to protect them. When this is done she covers up the hole carefully. That is all she can do for her young. When cold weather comes she dies; but the eggs are quite safe in the ground; the warm spring sun hatches them, and the young come out of the ground like their mother, except that they are very much smaller, and have only scales for wings.

They feed upon green vegetation and grow very fast. Soon they become too large for their skin, which bursts along the back. They work themselves out of it, and a new one underneath is ready for them. In this way they get six different coats while they are growing.

Short-winged locust.

Locusts sometimes become very numerous, especially in sandy regions. Great swarms of them migrate in search of food, and devour everything green in their way. A traveler in India says that he once saw a cloud of these locusts passing overhead so dense as to darken the sun. He estimated the cloud to be about five hundred miles in length.

Sometimes these migrating swarms are driven out to sea by the wind, and becoming exhausted they fall into the water and drown. The dead bodies are washed up on the shore in great banks, in some cases fifty miles in length and three or four feet high.

In order to study insects I made a wire-screen cage. In the bottom I put a few inches of sand, into which I set pots containing grasses and other plants for the insects to feed on. I was able to find out many interesting things about these insects by means of an opera-glass.

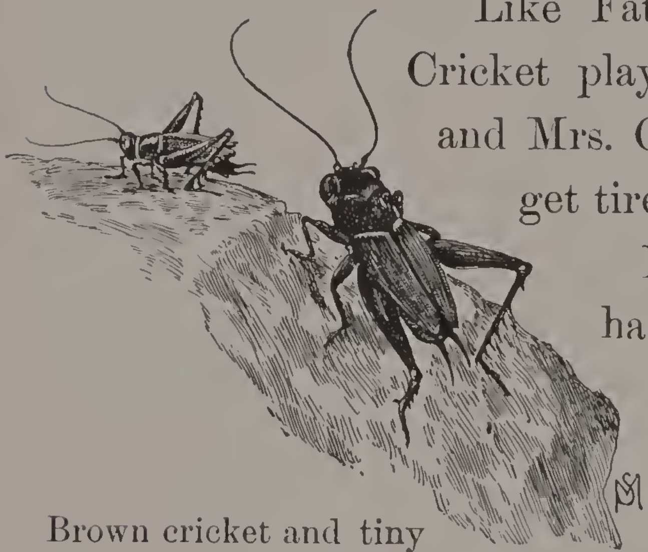
Wing of grasshopper, showing the veins running diagonally across, that serve the insect for fiddle strings.

In this way I discovered that Mr. Grasshopper is a fiddler. I saw him use his hind legs as a bow and his wings as a violin. I noticed that some grasshoppers did this one way and others in a different way. Some played one tune and some another. Like beginners in music, they could play but few tunes. Mrs. Grasshopper neither sings nor plays. She seems to be satisfied to listen to her husband's performances, which he keeps up pretty steadily.

THE CRICKET.

In my cage were several black insects. They are called crickets. The name probably comes from the chirping sound that they make.

This insect has a chubby body. Like the grasshopper, he has long antennæ, long hind legs, and straight wings which lie along the back. The male cricket has two long bristles or styles at the end of his short abdomen, and the female has a still longer egg-layer, or ovipositor, as it is called. She makes a hole in the ground with this, in which to hide her eggs away from enemies. She sometimes lays as many as three hundred in a packet.


Brown cricket and tiny spotted cricket.

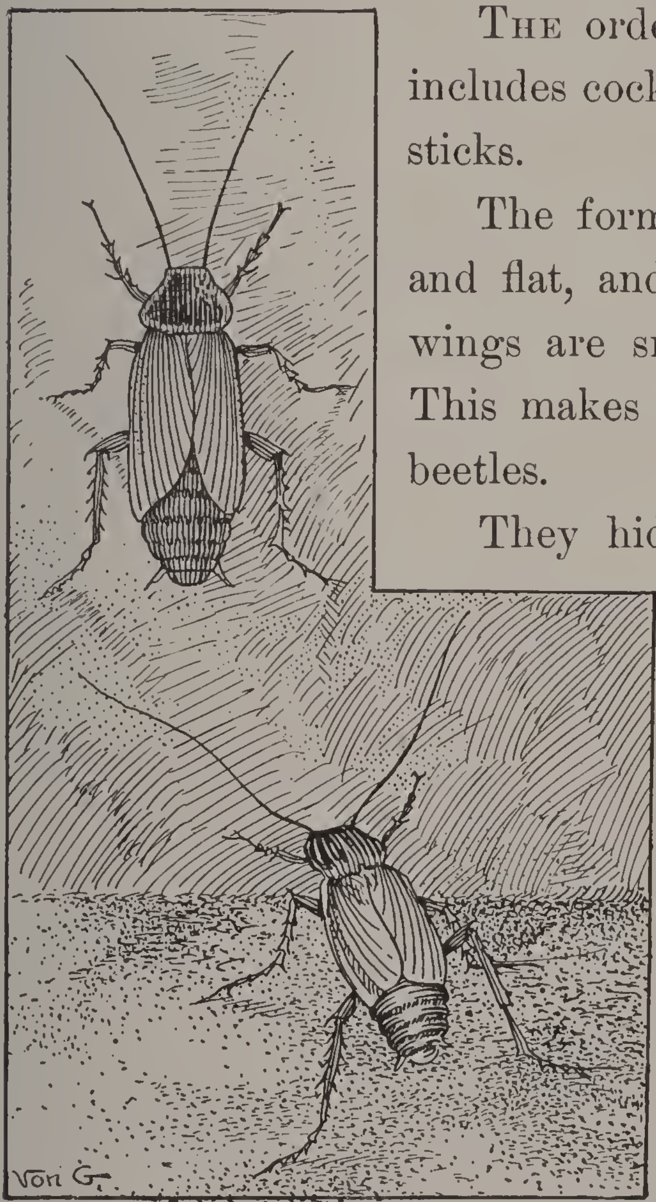
Like Father Grasshopper, Mr. Cricket plays his violin for hours, and Mrs. Cricket never seems to get tired of his music.

He doesn't seem to have a larder, and why should he? He finds plenty to eat as he goes along. If he doesn't have enough juicy green leaves and stalks, he doesn't mind making a meal or two from your leather shoe or trousers, or even from the handles of your old tools.

When cold weather comes he likes to get into our houses, somewhere near the fireplace, and 'tis well for him too. Jack Frost would freeze the life out of him if he remained out of doors.

There are many queer ideas about the cricket in different parts of the world. Some people think if one gets into the house and chirps his little song, that some friend or near relative will soon die. Others think it is a sign of good luck to hear the cricket on the hearth.

THE COCKROACH AND WALKING STICK.



Cockroaches.

THE order Or-thop-ter-a also includes cockroaches and walking sticks.

The former are rather broad and flat, and their front pair of wings are smooth and leathery. This makes them look much like beetles.

They hide in cracks during the day, and come forth in the dark to feed upon almost everything in their way. They give out a disagreeable odor, which they leave upon everything they touch.

They abound in warm countries,

where they are great pests. One kind, called the drummer, found in Cuba and other islands, is about two inches long, and makes a drumming sound on wood which is very annoying.

Walking stick.

The walking stick is one of the queer things of Nature. It has a very slender body, six legs, and usually no wings. Once in a while one is found with wings which are shorter than its body.

It is quite probable that many centuries ago all of this family of insects had wings, but as their manner of life changed their wings became useless and gradually grew smaller, until they have almost disappeared.

Walking sticks are found upon plants, and look so much like the objects on which they live that it is difficult to find them.

THE KATYDID.

Did you ever hear an insect say "Katydid, katydid, she did?" It is called katydid, and I am sure you can guess why.

This insect looks much like a green grasshopper, and on account of its straight wings it belongs to the same order of insects. The cricket and earwig also belong to this order.

The name of this order is Orthoptera (ortho, straight, and ptera, wings), straight wings.

The katydid never seems to be in a hurry. He says his three syllables slowly, and waits a minute or so before he repeats them, quite in contrast in this respect with some of his cousins, who nervously and continuously saw away.

KATY-DID

The male katydid has a sort of a drum on the back between the wings, which you can easily see. He rubs his wings against the drum to make the noise which sounds to us like "Katydid, katydid, she did."

There is an interesting story about the katydid's name. Two sisters, Katy and Dora, loved the same young man, whose name was Oscar. When Katy found out that he loved Dora she began to hate him, and gave way to this hatred until she secretly murdered him. In those days there were no detectives to hunt down murderers. But Jupiter knew what Katy had done, and wished to punish her. So he changed Oscar's spirit into a new kind of insect, which lived in the trees. One day, while Oscar's friends were walking about under the trees and asking each other who might have killed Oscar, they heard the words "Katydid, Katydid, she did." It was the new insect, and so Katy, the murderer, was found out. "Be sure your sin will find you out" has often come true.

THE FIREFLY.

Man has invented a lantern to give him light in the dark. Did you ever see an insect that furnishes its own light? There are not only insects, but many other small animals in the warm seas that have the power of giving out light. The light bearers best known to us are the firefly and the glowworm.

The firefly is the lamp carrier among bugs. He has the power to give out light from the hind part of his body whenever he wishes. What that light is, and how he produces it, I do not know.

Girl in Dutch Guiana reading letter by light of fireflies.

The firefly is a slender beetle a little more than half an inch long. His hard wing-covers form a sheath under which the true wings are folded. For this reason he belongs to the order of insects called Co-le-op-ter-a. Coleoptera means sheath-wings. This order includes all beetles.

The larvæ of the firefly look like worms. They live on plants and insects, some of them on snails.

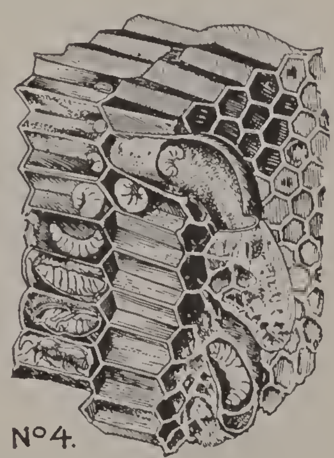
The Mexican Indians sometimes tie a number of fireflies to their hands, and they serve very well as a lantern. One traveler tells us that he put some of them into a bottle, and they produced light enough to read by. In Dutch Guiana and other parts of South America little wicker cages filled with fireflies are used as lanterns.

In warm countries there are many fireflies, and most of them are larger than ours. One kind in South America is an inch and a half long.

THE BEE.

WHAT a busy little creature the bee is! You never see her idle or flying hither and thither just to kill time. She seems to have a purpose in everything she does.

I have not seen the bees on many of the early spring flowers, but they are eager for the tree blossoms, especially those of the maple and linden. After these the raspberry flowers supply them with nectar, and as soon as the white clover puts forth its blossoms the bees are in them. The red clover hides its nectar in tubes too long for the bees to reach. The



Honeybees: No. 1, worker; No. 2, drone; No. 3, queen; No. 4, portion of honeycomb, showing cells of workers and royal cell.

bumblebee gets that. Then the bees visit sweet clover and the corn blossoms. In the fall a field of buckwheat affords them special delight. The nectar from its blossoms makes rather dark honey.

Here the bee is a friend to both the buckwheat and the farmer, for, while she is gathering the nectar with which to make honey, she is helping the blossoms to ripen the seed from which the miller makes flour, and both buckwheat cakes and honey meet again on our breakfast table in winter.

After bees have once found a field or a tree full of blossoms they can go straight to it. They never lose their way. I wonder how they know it. Do they remember the way, or the objects which they pass, or the direction?

Sometimes in spring they are chilled by the cold, and fall down in sight of the hive, unable even to crawl into it. When a storm comes up they fly home in great haste, and if they are overtaken by it they hide under the leaves or in the grass, but nevertheless many perish. In this and other ways hundreds of the inmates of the hive are lost every year.

Did you ever see the bee go from flower to flower until her hind legs were thick and yellow with the pollen which she gathers and takes home to her hive?

It is fun to watch her unload the pollen. She scoops it out of the groove in her thighs with the spine that projects from the second leg, and with the front pair of feet puts it in her mouth. Then she stows it away in a cell.

The bees are sure to find the first blossoming catkin on the willow tree and gather its pollen, from which to make fresh bee pap. The old supply in the fall has probably given out or lost its fresh

Interior of a beehive, showing the comb cells partly filled with honey and partly empty. Worker bee, queen, drone. Hind leg of bee loaded with pollen.

flavor. It does not seem to keep as well as the honey.

How does the bee gather the honey? She sips the sweet nectar from the flowers and puts it away in the antechamber of her stomach, a sort of crop.

When the bee gets home she presses the flower honey out of her crop into the six-sided cells of the comb which some of the other bees have made ready. As the honey passes over the tongue, it is mixed with a very little formic acid, which comes from a gland through a tiny slit near the root of tongue. The acid seems to cure the honey and it will then keep many years.

The honeycomb is made of wax. You may think that the making of the comb amounts to very little compared with the making of the honey, but the bee surely can not think so. Those who have watched the making of the comb say that it takes more time and patience than it does to fill the cells with the honey.

The waxmakers first fill themselves with honey and retire to a quiet place in the hive, where they wait several days, until small drops come out through the body between the rings of the abdomen and dry into tiny wax scales. These the bees take off, and with them build up the cells of the comb.

How delicate these cells are! Their walls are no thicker than a sheet of note paper. How regular! One seems to be just like the other. I wonder if they are all exactly the same size. Some day I mean to measure them with compasses.

I have said "she" in speaking of the bee, and that is correct, because the working bees are dwarfed females. There are males in every hive too, but they do not work. They are lazy, clumsy, broad-shouldered fellows, always humming, but doing nothing useful. That is why they are called drones. When the weather is fine they sometimes fly out in the fresh air, not to gather honey, but simply to enjoy themselves. They live to eat, and, like most people who spend their lives in that way, are not long wanted.

The workers get rid of them about August, and the drones seem to know when their end is near; for, instead of buzzing about everywhere, they hide away in fear in the hive making a pitiful noise. Sooner or later the workers starve them, or pull them to pieces, and drag them out of the hive. The drones do not defend themselves; it would be useless to attempt it. I have seen as many as three workers attack a single drone. One took hold of the head, another of the hind leg, and the third stung him to death in the thorax.

The queen is longer than either the drone or the worker, and is somewhat different in shape. She looks very queenly, and you would know her at first sight.

She is the only mother bee in the hive, and goes from cell to cell laying an egg in each one. Although she lays about one hundred and twenty eggs an hour, it takes several weeks to supply all the cells of a large hive.

In three days little larvæ, which look like small, white worms, come out of the eggs. They are well cared for by the nurses, and in five or six days have grown to their full size and stop eating. The workers then seal over the little cells, leaving many small air holes in each. The larvæ spin silken cocoons and begin their sleep of ten or eleven days. At the end of that time they work their way out of the cells. They are now perfect bees of a light-gray color. Then the nurses bring them food and pull off the thin gossamer web that covers them, leaving them as neat and clean as a new pin. The young bees remain in the hive a week or two, doing hive work, such as nursing and cleaning, before they begin to gather honey.

The workers seem to have it in their power to raise queens whenever they need them. They take an ordinary larva and enlarge the cell in which it lives. They also feed it plentifully with a honey preparation, that has been called "royal jelly," or bee pap, made by the bees themselves.

There is not room enough in any hive for two queens. The workers seem to be very careful to prevent a contest between queens, but this can not always be avoided if two queens happen to be in the hive at the same time. The rivals are sure to attack each other and fight to a finish. In such a case the workers gather round and seem to take as much interest in the contest as do people in a prize fight. But I am sure they are not in the habit of betting on the winner.

The bees sometimes keep the young queen a prisoner in her cell until, for lack of room, a part of the hive has taken the old queen and gone out in search of a new house. This is called swarming.

When they swarm they pour out of the hive in a great hurry and whirl about each other, with the queen in the center of the swarm, all the while making a soft, humming noise. Soon the whirling mass moves off, at first slowly, over fences and fields. Sometimes they settle on a branch to rest, and possibly to send out a few workers house-hunting. They prefer a hollow tree for their home. In this respect they are still wild bees, and no matter how long they have been in hives, when they swarm they still want to go to the woods.

There is great fun in following a swarm of bees. Usually they go on in the direction in which they

Bees swarming.

start, unless high objects make them turn aside. They have sometimes been made to alight by throwing water on them.

Every hive is a little republic managed by the workers. It is incorrect to say that the queen rules as she pleases, for she must obey the workers even in the matter of swarming. She is truly not born a queen, but made one. When room in the hive becomes scarce, the workers find a new home, and a part of the colony take the old queen and set out to occupy it. She is more a mother than a queen, and all the bees are her children. They always wait upon her carefully, for without a queen the colony would soon die out. The queen is the egg-layer, and when there is no queen there are no eggs from which to raise young bees. Workers have been known to steal eggs from other hives, from which to raise a queen; or even to feed some of their own number with special food in order that they might lay eggs. Such eggs, however, hatch only drones. The life of the colony therefore depends upon the presence of the queen.

THE BUMBLEBEE.

The bumblebee is also called the humblebee, and by the Germans "Hummel." She probably gets her name from the sound she makes while flying about.

Let your eye follow her as, dressed in black and yellow, she zigzags through the hot, sunny air. Watch her as she dips clumsily into the blossoms and drowsily hums from flower to flower. Bumblebees make us think of lazy summer days, but they are neither lazy nor useless.

The colony of bumblebees consists of queens, males, and workers. Both queens and workers are armed with terrible stings.

The queens of the bumblebees are not so jealous of each other as are the queens of the hive, for a number of them will live peaceably together in the same nest. One large nest was found to contain one hundred and seven males, fifty-seven queens, and one hundred and eighty workers.

The males and workers die during the winter. The queens alone survive because they hibernate. As soon as the warm spring weather comes each queen goes forth to found a colony of her own.

She usually builds her nest in the ground, selecting a bank or some other dry place, often the old nest of a field mouse. She makes a waxy comb of a few large, brownish cells, in which she lays her eggs. She adds cell by cell as she increases the colony. There is usually very little honey to be found in her nest.

When the bumblebees' nest is disturbed they become very angry, and fiercely attack the intruder. One day, while ploughing in the field, I disturbed a bumblebee nest. The angry inmates at once rushed

The nest of the bumblebee.

out and attacked both me and my horses with such vigor that they put us to flight. I put on an overcoat and buttoned it tightly up to my chin, a veil over my face and neck, and mittens on my hands, and went out again to their nest with a good deal of confidence. As soon as I approached, some of them gave the signal and the whole colony came buzzing out again to renew the attack. There was a little hole in the top of my hat which I had forgotten, and some of them crept in there and stung the top of my head. Others crept up under my coat, and once again I was put to flight. But I was not going to be defeated so easily. That evening, when they were all quietly sleeping, I took an armful of straw, laid it on their nest, and smoked them out.

The bumblebee makes itself very useful to many flowers, especially the red clover, by carrying the pollen from one blossom to another. This mixing of pollen is necessary to make good, ripe seed.

It is impossible to raise red clover seed in Australia because there are no bumblebees there. At two different times colonies of bumblebees were taken there, but for some reason they soon died out.

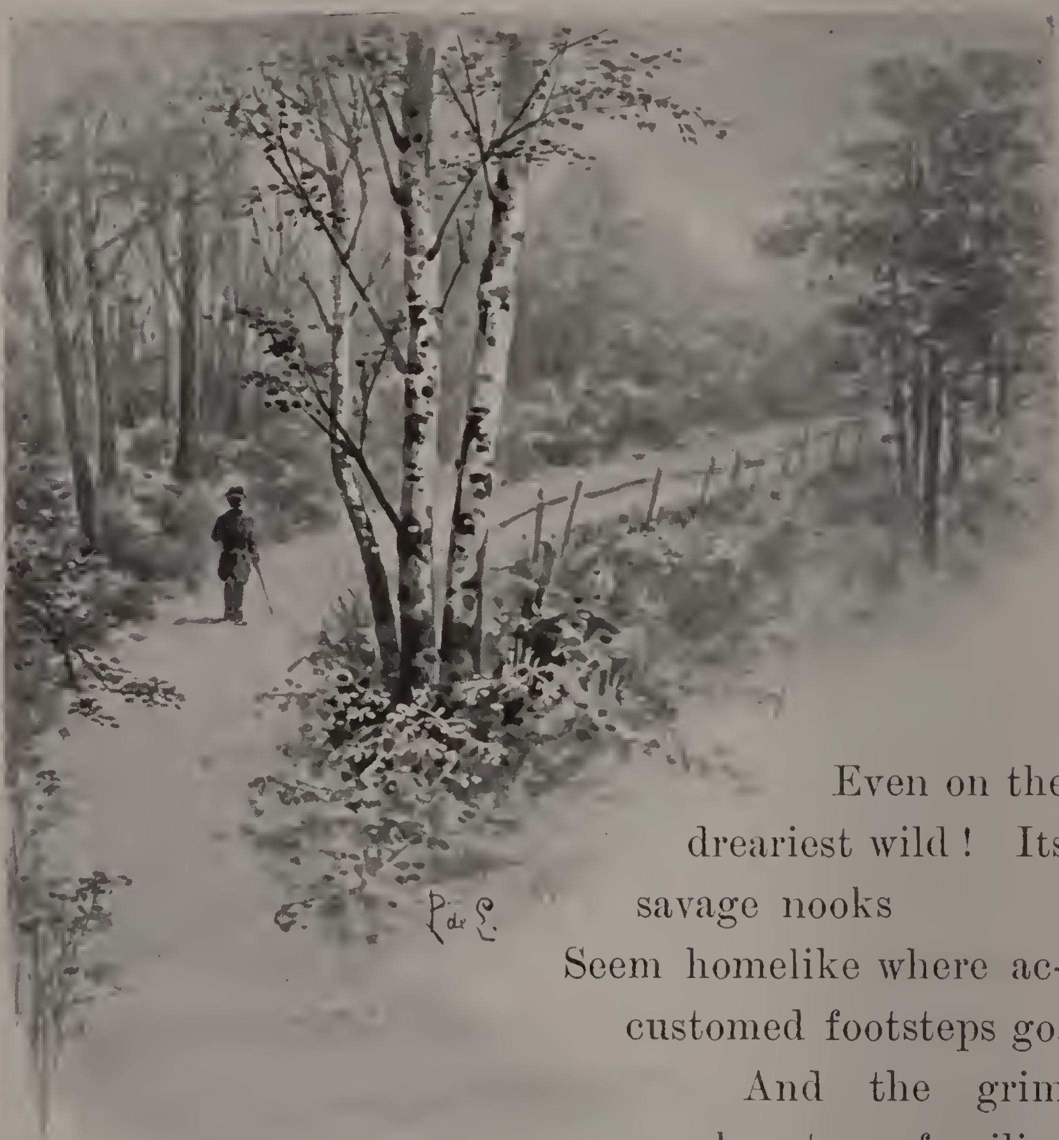
Mr. Darwin, who was a great observer, learned that in a certain field there was much clover some years and other years very little. He wondered why; he then began to look for the cause, and discovered that the clover crop depended on the number of bumblebees. He found that field mice destroyed the bumblebees' nests; that when there were many mice there were few bumblebees; and that when the people in the village near by had many cats, which destroyed the field mice, there were few mice to destroy the bumblebees' nests. The conclusion was evident: many cats, few mice; few mice, many bumblebees; and many bumblebees, much clover.

THE FOREST.

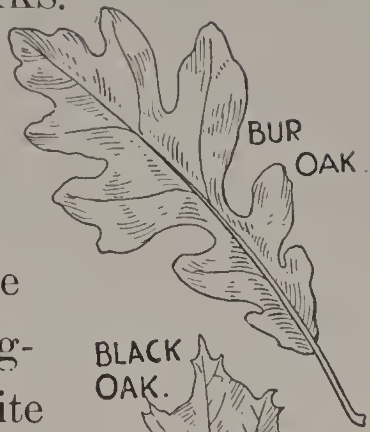
My way to school lay through a small forest. Tall trees stood on either side of the path. The more I learned about the trees the more secrets they seemed to have for me. I saw them in the winter when their branches were leafless. I saw them in the spring as soon as the buds began to swell. I watched their tiny blossoms as they covered themselves with yellow pollen and then changed into the winged seeds, which later were scattered across my pathway. I saw the leaves unfold and cover the trees with green, and then change to yellow and brown, red and scarlet, setting the forest on fire. Every tree became an object of interest to me, and I learned the names of all the varieties in that forest, and, what is better, their manner of life and growth.

" 'Twas a pleasant toil to trace and beat,
Among the glowing trees, this winding way,
While the sweet autumn sunshine, doubly sweet,
Flushed with the ruddy foliage, round us lay,
As if some gorgeous cloud of morning stood,
In glory, 'mid the arches of the wood.

" A path! what beauty does a path bestow



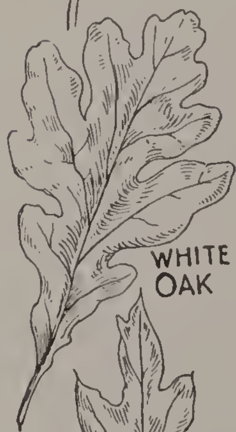
Even on the
dreariest wild! Its
savage nooks
Seem homelike where ac-
customed footsteps go,
And the grim
rock puts on familiar
looks." BRYANT.



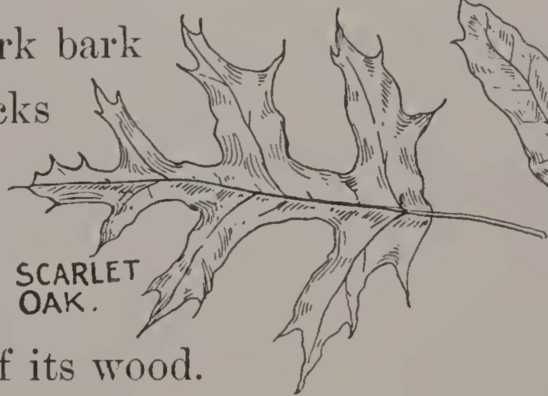
THE OAKS.

THE oaks always spoke to me of strength and dignity. There were the white oak, the red, the bur or moss-cup, and the black or yellow-barked oak.

The leaves of these oaks are all deeply lobed and very much alike. Yet if we examine them carefully we shall find differences.



I could distinguish the various kinds of oaks best by their bark. The white oak has a gray, rather thin, scaly bark, which in old trees peels off in short strips. The bark of the bur oak is thicker and rougher, and does not scale off as does that of the white oak. The red oak has dark bark with deep cracks in it. This variety gets its name from the reddish tinge of its wood.



The bark of the black oak is very much like that of the red oak, but it is a little darker and rougher, and the inside is an orange yellow. For this reason it is also called the yellow-barked oak.

Now I want to tell you about the blossoms that I found on the oaks and other trees in this forest. Perhaps you have said to yourself, these trees do not have blossoms.

I thought so too at one time, but when I began to observe the trees all the year round, I found out some very interesting things about their blossoms.

Everybody has seen the blossoms on apple trees, and on plum, pear, and cherry trees, and knows how beautiful and fragrant they are. These are all simple roses, and some of them are quite as sweet as any double rose. The wild crab blossom is considered the most delightfully fragrant blossom of the rose family.

But how about the blossoms on the oak, elm, and pine? I grant they are not as showy, but they are quite as wonderful and interesting as any fruit-tree blossoms.

I began early in the spring to watch the blossoms. I saw the blossoms of the Western cotton tree first. They come long before the leaves. In fact, the blossoms on most trees appear before the leaves.

Double roses.

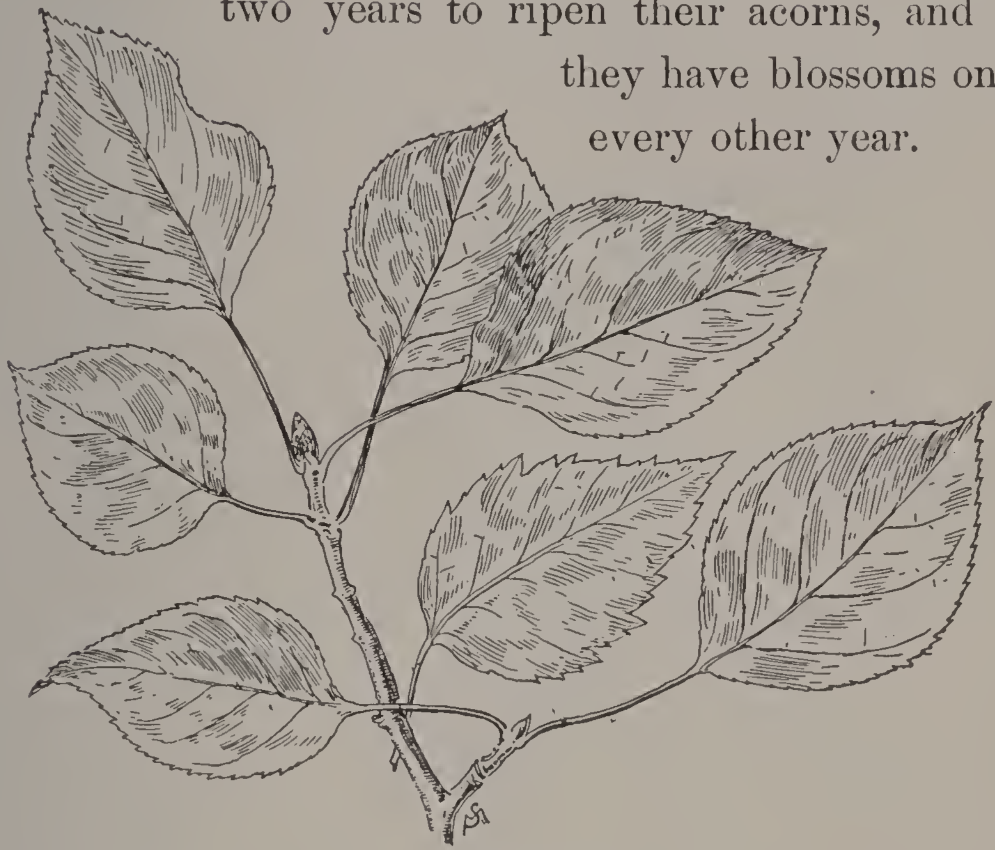
Next I saw the maple blossoms. The ash and oak blossoms were among the latest to appear.

Like the blossoms of many other forest trees,

Red oak.

those of the oak are not perfect, because they have neither calyx nor corolla. Even the stamens and pistils do not grow in the same flower. The stamens are in the form of catkins. The pistils are small, stunted-looking things, but they are the part of the flower which bears the acorns.

The red and the black oak require two years to ripen their acorns, and so they have blossoms only every other year.



Crab apple.

LINDEN TREES.

Another tree was sure to attract attention. It was of good size, and had very large, almost circular leaves with saw-tooth edges. I found some leaves that measured six inches in width. One kind had smaller leaves, only three inches across.

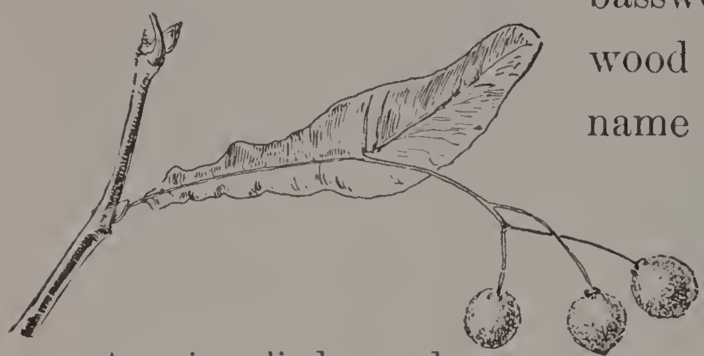
Basswood, American linden.

The large leaves made such a dense shade that not even weeds would grow beneath them.

Basswood, American linden.

These trees have the well-sounding name of linden. In the city of Berlin there is a wide street that has lindens planted on either side, and for this reason it is called "Under the Lindens."

The small, cream-colored flowers in spring are very sweet. The bees find some of their best honey in linden blossoms. This honey is called basswood honey. Basswood is the common name for linden.



American linden seed.

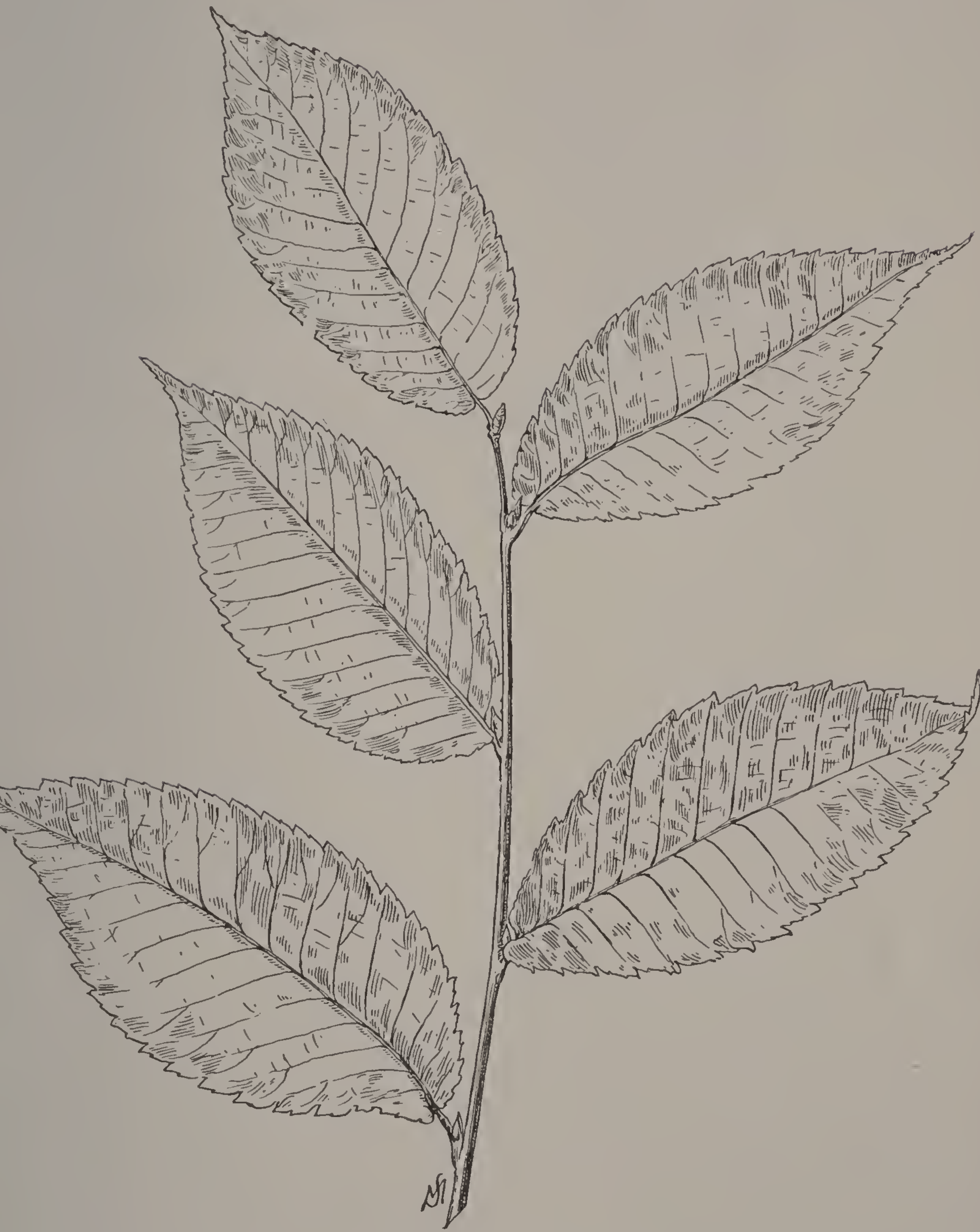
The most curious thing about the linden family is the wing of its seed. This wing is a leaflike bract, the lower part of which is grown against the stem which bears the little, pealike seeds.

The outer bark of the linden is dark gray, and in old trees full of deep cracks, but the inner is fibrous and tough. We often used this bark instead of ropes for swings.

THE ELMS.

The forest contained a number of American or white elm trees. This splendid tree has been called the home tree, because it is planted so much about our homes, especially in the eastern part of the United States.

The crown of the elm takes many forms. One is the vase form. The roots start out from the



Slippery elm.

trunk above ground and form the foot of the vase. The branches form the bowl, and the little drooping twigs the turned-over rim.

The sheaf form is a little taller than the vase form. The plumose shape has most of its branches on one side, so that it resembles a long, wavy plume. The fan-shaped is not so common. There is one of this form in Central Illinois that covers more than an acre. Large meetings have been held under its broad, shady branches. There is an elm at Plymouth, N. H., so large that four men taking hold of hands can scarcely encircle its trunk.

The leaf of the elm is rather rough. That of the red elm is rough on both sides, has a pointed apex, and a double-toothed margin.

We did not have much chewing gum, but we had what is more wholesome—the inner bark of the "slippery" or red elm. This bark has a pleasant odor, and is sold in drug stores as a medicine. When soaked in water it becomes soft and slippery.

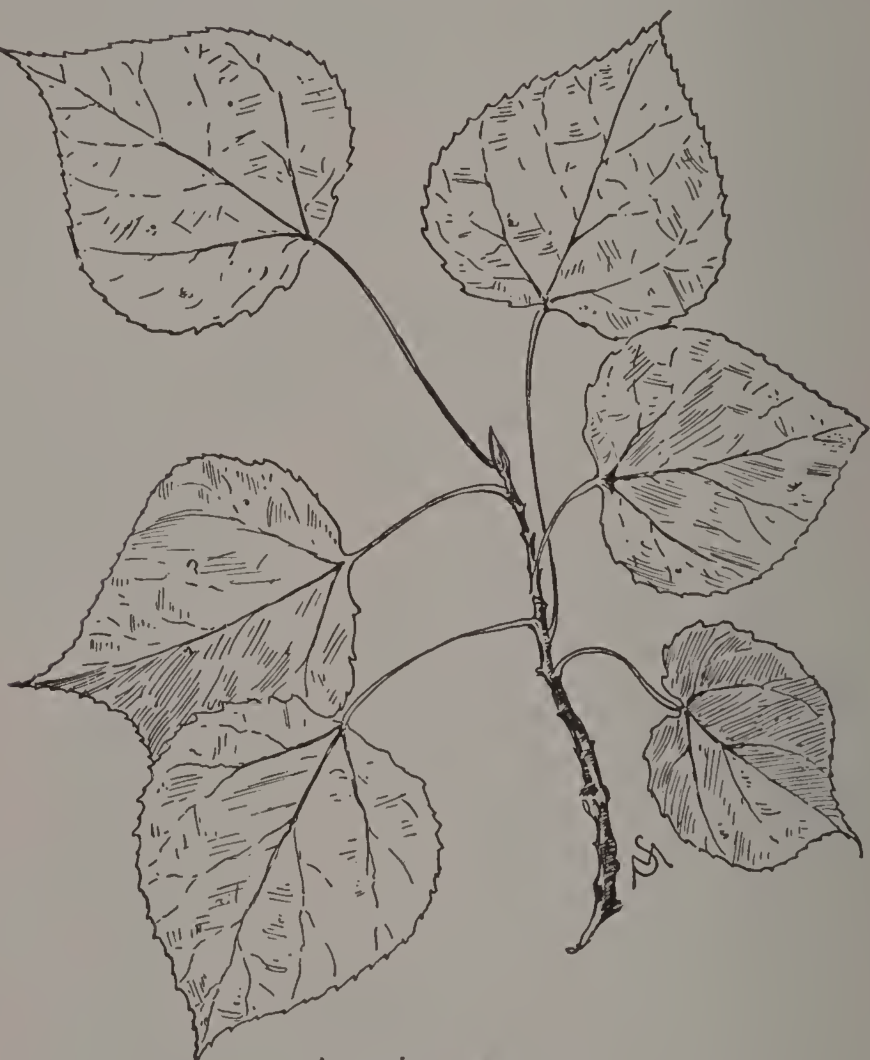
The rock or cork elm was found along the creek. The wood of this elm is tough, and can be split only with great difficulty. Elm wood is much used for furniture and for fence posts.

Typical forms of elm trees.

Sheaf. Vase.
Fan. Plume.

THE POPLARS.

Another kind of trees stood in groups on the higher ground. These trees had straight, slender, white trunks, which could be seen through the open



American aspen.

spots in the foliage of other trees. They looked like the white trunks of the paper birch, but the leaves were a lighter green, and the slightest breeze made them tremble all over the branches. When a gust of wind struck them they seemed to slap each other in laughing glee. I often stood and watched their antics.

Why do they behave so? They can not help it. They are fastened to the tree by a petiole or stem which is flattened vertically. If you will hold one in your fingers and blow at it sideways, the leaf will tell you its own story. You will make a discovery.

These trees are straight, not over forty feet high, and have small branches. They are a variety of poplars known by the name American aspen, or quaking asp.

In the East, where they grow near good water power, the wood of these trees is ground to a pulp and made into paper, which is used for pails and other useful articles.

Along the low grounds stood a number of poplars nearly a hundred feet high and about two feet in diameter. They had rough dark-gray trunks. Their leaves were larger and their margins more jagged than those of the American aspen.

As soon as this tree is covered with leaves its little catkins change to green, berrylike balls, which contain the seed. The seeds have a pappus or feathery substance attached to them of fine, white fibers, which look like cotton. When ripe, the little balls

Young Lombardy poplar.

open and the wind scatters the seeds. Sometimes these cotton fibers almost cover the ground in the neighborhood of the trees. You will at once see why the tree is called the cottonwood.

This tree has been frequently planted as a shade tree in the prairie States. Its wood, like that of all poplars, is rather soft and brittle. As fuel it burns rapidly, but gives little heat. Being odorless, it is now much used for packing-boxes for crackers and other food. It goes by the name of whitewood.

Perhaps you will find another tree growing near some home which you will at once recognize as a poplar from its trembling leaves. It has many small, switchlike branches, which grow almost straight up beside the trunk. The tree grows easily and rapidly, and for this reason, in Iowa and some other States, it has been planted close together in rows to form wind-brakes; but when it gets to be a dozen or more years old some of its branches begin to die, giving it a ragged appearance. It is a native of Italy, of the province of Lombardy, and in that way it gets its name, Lombardy poplar.

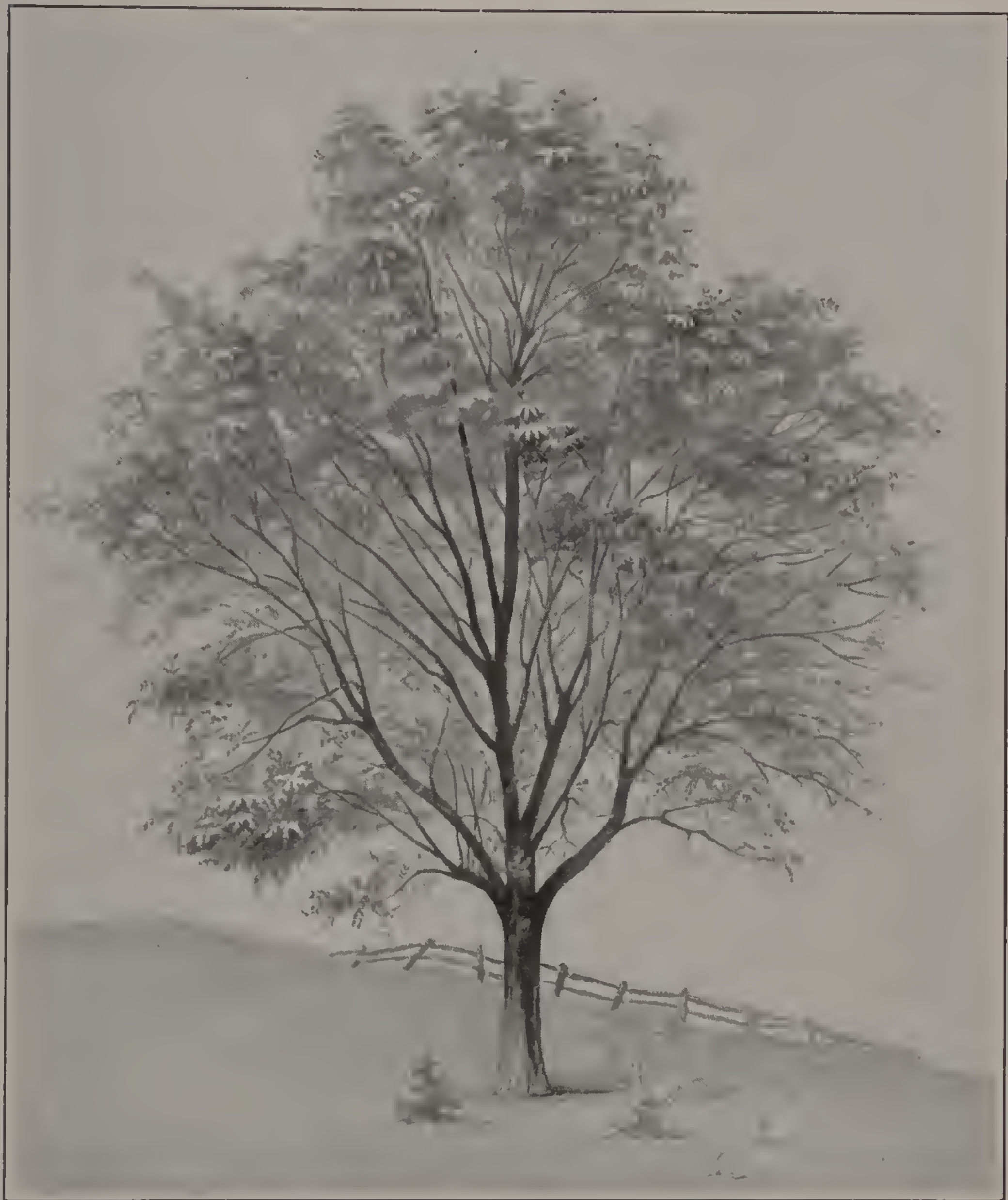
WALNUT AND BUTTERNUT.

There were two other kinds of trees in the forest that attracted our attention, especially at nutting time. They were tall, rather large trees, with stout, spreading branches, and dark-gray furrowed bark, which was smooth in the young trees. These were the black walnut and the butternut or white walnut.

Both have a compound leaf; the black walnut has as many as twenty-one leaflets on a stem, and the butternut seventeen. The flowers in spring are long, thick tassels, four to six inches in length.

The nuts ripen with the first frost. The boys eagerly look for the frost, for they know that the next day's wind will bring many of the nuts to the ground. The nuts still remaining on the trees often tempt brave boys to climb into the branches after them, but they usually find it a very dizzy job.

The chipmunks and red squirrels are busy, too, getting their share of the nuts. One day while we were out nutting I sat down under a large walnut tree. It was not windy, yet the nuts kept on falling, one by one. I wondered what made them fall, and soon discovered two red squirrels up in the trees cutting off the nuts as fast as they could with their



Black walnut tree in October.

sharp teeth. I said, "Thank you, Little Sharp Eyes—thank you; you are very kind to help me."

The black walnut is round, the white walnut or butternut, lemon-shaped. Both have a pulpy, rough, green husk, which has a bitter juice that stains the fingers, so that for a week or two it may be easily seen who has been nutting.

The wood of the walnut is dark purple brown, while that of the butternut has a reddish tinge.

Many a noble walnut tree is cut down to satisfy the greed of its owner, as the lumber brings a high price. These trees which once were abundant are now becoming scarce.

The largest walnut tree I ever heard of was recently cut in southern Indiana. The stump measured nine feet across, and the first limb was sixty feet from the ground.

The English walnut is not so large as the other varieties, but its nut is more valuable. Orchards of this tree may be planted in the southern part of the United States and prove very profitable.

THE HICKORY TREE.

The boys and squirrels, too, were sure to find another nut in this small forest. It was not quite so large as the walnut.

Its shell, which is less pulpy, separates naturally into four equal or nearly equal parts, and the nut is slightly angular. The flavor of the nut is so excellent, that it is preferred to the walnut and butternut.

Shagbark hickory.

The hickory tree which bears these nuts is found in nearly all the Northern States, and even as far south as Florida. It often grows in groups or colonies.

I found two kinds in our forest. One has dark-gray bark which hangs in strips from the tree and gives the trunk a ragged look, from which it gets the name shagbark, or shellbark. The other kind we called bitternut. The bark is somewhat furrowed, but does not peel off.


Bitternut—portion of leaf.

There are six other kinds of hickory in the United States. One of them is the pecan. This one may be called the hickory of the South, because it thrives in the southern half of the United States.

The pecan-nut is smoother and has a thinner husk than the shellbark. It is oblong in shape like the kernel of a peanut.

The pecan may be planted for profit. An orchard will begin to bear in eight or nine years. It has been much improved by cultivation. I have seen pecan-nuts from one tree in Mississippi that were two and a half inches long, and had a very thin shell, on account of which they are called the paper-shell pecans.

All the hickories have a compound leaf. The shellbark has five and sometimes seven leaflets, and the pecan has from thirteen to fifteen. The leaflets are all pointed, and most of them are slightly hairy or downy on the under side.


Pecan-nut in husk.


Pecan leaflet.

These trees are both handsome and useful. The finely shaped head of soft, green foliage forms an object of beauty in forest and garden.

The wood is fine-grained, tough and elastic, and of a white color, except the heartwood, which is reddish. It is used for carriage wheels, handles and other articles requiring toughness, and vies with the hard maple as fuel.

THE HAZELNUT.

I MUST not forget to speak of the hazelnut which grew all round the edge of the forest. It is a shrub from five to eight feet high, has a stem one half to an inch thick dividing into branches near the top and bearing coarse, double-toothed leaves.

The blossom is a smooth, round catkin; the nuts are nearly round and incased in a bony shell. These nuts grow in bunches of three to five, occasionally only one or two. Each nut is inclosed in two thick, leaflike bracts or husks with fringed edges. These separate when the fruit is ripe.

There is a kind of hazelnut imported from Europe which is oblong and is sold under the name of filberts.

Hazelnuts.

The kernel of the hazelnut is solid. It is not divided, like the kernel of the walnut and hickory nut, by irregular partitions. The nut is easily picked and taken from its shell.

THE HEIGHT OF TREES.

Where is the boy that has never asked the question, "How high is that tree?" Every boy likes to make a guess at least. But I know a little boy who found out an easy way to measure the height of trees.

There was a tall walnut tree standing in his back yard. He spent many an hour in summer-time playing in its shadow. More than once he asked his mamma how tall she thought the tree was, but he did not seem to feel satisfied with her answer. He thought about it a great deal.

One beautifnl forenoon he suddenly ran into the house, and said: "Oh, mamma, I've found out!" "Found what?" asked his mamma. "I've found out how tall our tree is."

I'm sure you can not guess how he did it. He had nothing but a two-foot rule and a stake. He had driven the stake into the ground and tied his pull-rope to it. While he was swinging he noticed the shadow of the stake. He measured it and found that it was just as long as the stake was high. Then he said to himself: "If the shadow of the stake is as long as the stake, the shadow of the tree will be the same as the tree."

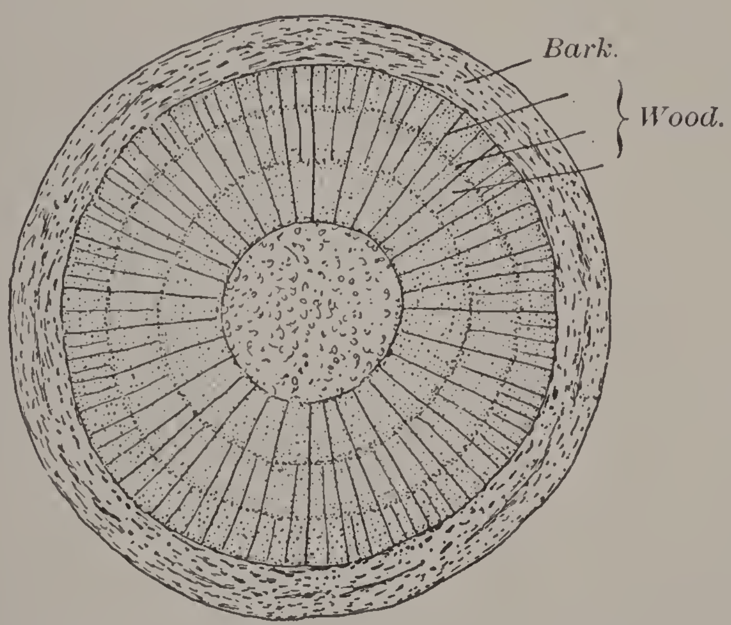
Measuring height of walnut tree.

He measured the shadow of the tree and found it to be sixty-two feet. "Our tree is sixty-two feet high," said he. And I think he was right. In the same way he measured the height of other trees and also of the house.

Twice a day the shadow of all upright objects will be equal in length to their height. Any boy or girl can find out what time of day that is by watching the changing shadows and then measuring the shadow of a post and of the tree. It is also true that twice a day the shadow of an object is twice its own height.

THE AGE OF TREES.

"I WONDER how old our tree is?" was another question that the little wide-awake boy had some trouble in answering. He took his mother's tapeline and measured his tree around the trunk a foot above the ground. "It is fifty-four inches," he said to me. "I wonder if it is as many years old." I told him I thought not.



Section of the trunk of a tree.

Then I showed him some pieces of wood cut from different kinds of trees. He soon noticed the rings at the ends. "What made these rings?" he asked. "Can we tell by the rings how old the tree is?"

"Perhaps you can," was my reply. "This piece was cut from an ash-leaved maple, the seed of which I planted four years ago. You see it has four rings. Here is one from a soft maple eight years old which has eight rings, and this is another which is twelve years old and it has twelve rings, as you see. Every year the tree adds one ring."

I took the little boy to a part of the woods where many trees had been cut down for cord-wood the winter before. The trees were red oaks. We counted the rings of ten stumps. The smallest one had twenty-five rings and the largest forty-seven. It was not always easy to count the rings, especially on the north side of the stump. We noticed, too, that the rings were a little thicker on the south side as well as more distinct. Do you think this is because the north side is so much in the shade?

Still the little boy was not able to tell the age of his tree, until one day he was taken to a sawmill where he saw a number of walnut logs. He at once measured the distance around them and found one about as large as the tree in his yard. He counted thirty-four rings on it, and concluded that his tree must be about thirty-four years old. He was quite certain that he was right.

I told him that he ought to measure and count the rings of other logs, and if he did so he would probably find that walnut trees which had stood near the valley grew faster than those on the hill, and therefore a walnut tree which grew on a hill and measured fifty-four inches would be older than one of the same girth grown near the foot of the slope.

The age of trees is very interesting. If we look at the end of a log, we shall find that the rings of annular growth are thickest near the center and become thinner as we approach the bark. In old trees the outer layers are so thin that it is difficult to count them. The larger the tree grows, the more wood it takes to make a ring of the same thickness.

Everybody has noticed the rapid growth of young trees. The branches extend outward and upward considerably every year. I measured the branches of an ash-leaved maple five years old, and found that in one year seventeen branches grew over fifteen inches in length, and five of them over two feet. Old trees lengthen their branches very little in a single year.

I planted an ash-leaved maple, or box-elder, as it is usually called. The first year it grew a shoot four feet high and three fourths of an inch in diameter. This made a ring three eighths of an inch thick. The second year it grew a ring only two eighths of an inch in thickness. From this we may see that the tree did not put on as thick a layer of wood the second year as the first, but it made more wood, as the ring was larger and the trunk taller.

Mr. Baldwin, of Florida, who has kept a record, claims that the rings do not always tell the true age of the tree. He says that he counted forty rings on the stump of a tree which he knows was not over thirty years old.

Hon. Robert Furness, of Nebraska, claims that a pig hickory, eleven years old, had sixteen rings; a green ash, eight years old, eleven rings; a coffee tree, ten years old, fourteen rings; and a bur oak, only ten years old, had twenty-four rings.

There are others who have similar records. They say that the difference between the number of rings and the age of the trees is caused by sudden and great changes in climate, such as often occur in Florida and in Nebraska.

In such regions a tree may start to grow very early in the spring, and after a few months, on account of very dry weather, may stop growing until heavy rains start it again. Some think that the growth of such a year will appear in two rings. I must say, however, that botanists, as a rule, do not believe that a tree has more rings than it is years old.

These statements ought to make us think and lead us to keep a record of trees that are planted in our neighborhood. The record should begin with the seed, and contain the dates of all droughts, and if any of the trees are cut down the rings should be carefully counted about a foot from the ground and the number put down in the record.

"Do not trees live longer than anything else?" inquired Willie one day. This question set us to thinking.

Man sometimes lives to be more than a hundred years old. We are told that in olden times men lived six, seven, or eight hundred years. Methuselah, the oldest man, was nine hundred and sixty-nine years old when he died.

Turtles are said to have reached the age of one hundred and fifty years. But there are trees that were old when Columbus discovered America, under which the Indians had made many a treaty with each other and smoked many a pipe of peace.

I heard a good botanist say that there are trees in this country known to be two thousand two hundred years old.

An old tree was cut down in the western part of England. On the stump seven hundred and eighty rings were counted, and then there was still more than three inches of wood near the bark where the rings were so close together that it was impossible to count them. There are cedars in Europe and the Holy Land that are doubtless more than two thousand years old.

ANIMAL LIFE IN THE FOREST.

Did you ever think that there are different levels of life in the forest? In the highest branches of the trees live the eagle, vulture, and hawk—the

Black bear.

upper-tens of bird society. A little lower we may find the homes of the woodpeckers and pigeons, and some of the squirrels; among the lower branches many of the song birds build their nests. On the ground roam the wild animals—the panther, the deer, the American lion, and the wild-cat, which looks like a large cat, except that its eyes are fierce and its thick tail is about two thirds as long as the cat's. Under the surface, among the roots, the chipmunk, rabbit, woodchuck, and sly but proud old fox make their dark dens, while the rifts and caves in the rocks are the hiding places of the wolf and the bear.

The animals of one level are more or less fearful of those in other levels Those in the highest level are the fiercest of birds; those in the lowest, the fiercest of beasts.

THE CHIPMUNK.

I WELL remember two white oaks that leaned over an old rail fence. They seemed to have the same root. One of them was hollow, and was the doorway to the happy home of a family of chipmunks. They were very cunning little creatures. I often saw them skip along the fence between the rails as I passed by within a few rods of the trees.

The chipmunk is a bright little fellow, always at work. Sometimes he is called the ground or striped squirrel, but his most familiar name is chipmunk. He is a cousin of the red squirrel, but they do not seem to get along together very well.

He is yellowish-brown above and lighter below. You can easily recognize him by the five black and white stripes down his back. His large bright eyes watch every move you make. He is not a good climber like the red squirrel, but he is clever at digging a hole in the ground, where his naughty cousin can't get at him and his pantry.

Chipmunk scolding.

He goes to sleep as early as October, and stays in his warm winter bed till March or April. During that time he wakes up now and then to eat a little.

About the end of April the chipmunk has a family of from four to six little ones, and then he has plenty to do. As soon as they are old enough to leave the nest, the whole family come out for a grand scamper along the fence. I often watched the merry little creatures chasing each other around, playing hide-and-seek.


The red squirrel.

About the end of August Father and Mother Chipmunk think it is time for the little ones to get to work.

So they all go nutting. It is very funny, indeed, to see them coming home with their cheeks so puffed out that their little noses are almost hidden. They look as if they had the mumps.

But they are only carrying home some nuts or seeds in the pouches in their cheeks which are made for this very purpose. The chipmunks are regular little misers, and work very busily till they have a wonderful supply of food—more than they can eat during the winter. They hide it away very carefully from the red squirrel and from other enemies, in a storehouse which is near the nest, so as to be handy.

The entrance to their home is almost always under some stump or rock, and opens into a passageway about ten or twelve feet long. This passageway leads straight down for some distance, and then slants upward toward several chambers. One of these chambers is the nest, which is lined with dry leaves. The others are used for storehouses.

Chipmunk.

Sometimes there is a second or even a third entrance, but all of them are well hidden, for the chipmunk knows that his enemies, the sly weasel and the ermine, are always on the watch to find his home and family.

THE FLYING SQUIRREL.

This reminds me of the flying squirrels which had built a large nest of leaves in a small red oak not far from the chipmunk.

I first discovered the nest in the autumn, after the leaves of most of the trees had fallen. The nest was even larger than a crow's. As I was standing and looking at it one windy day, I saw what I thought were leaves blowing away from the tree, first one, and then another, and then a third. I soon discovered that they were not falling leaves, but flying squirrels, sailing down from the branches near the nest to the lower branches of another tree some thirty feet distant. Then they ran up to the top of this tree and sailed off again as before.

Flying squirrels.

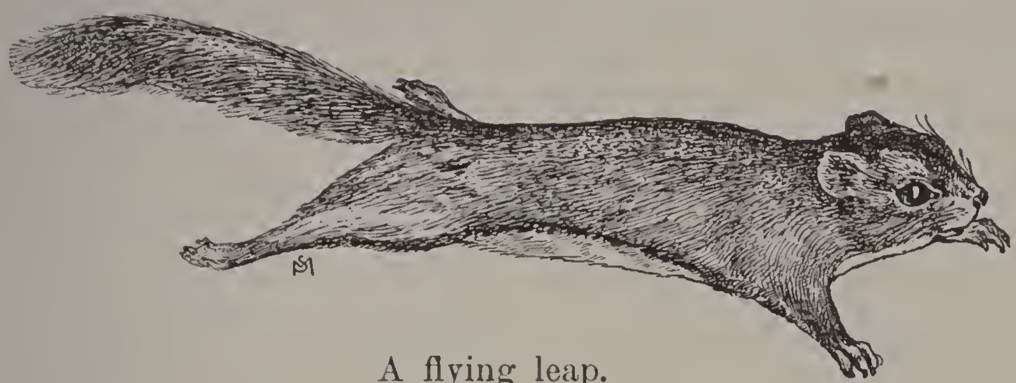
These squirrels do not possess wings, but have a loose skin on each side of the body, extending from the front to the hind feet, and when they fly, or rather jump, from one tree to another, they stretch this skin by spreading their feet as far apart as possible.

I know a little boy who watched a flying squirrel and made up his mind that he could fly too by tying a blanket to his wrists and ankles. He was just about to spread his arms and fly off the porch roof, when his father appeared and told him he had better begin by jumping from the table which stood in the yard. He did so, but after that he did not care to try the porch roof.

The flying squirrel builds his nest in a tree, but often puts his storehouse in another tree some distance away. He begins his sound winter sleep early in November, and we do not see him again till March. Sometimes, however, he wakes up and makes a flying visit to his storehouse to get a bite or two.

I did not see the flying squirrels out very often, for they usually do not appear till after sunset, but they are then very lively. The flying squirrel, the bat, and the owl are a wide-awake trio in the forest at dusk. Though the flying squirrels live in the open sunshine, and do not burrow in the ground like the chipmunk, they seem to be blinded by the bright sun during the day. The little ones are easily tamed and make cunning pets.

On a cold day in midwinter I found a thirteen-striped gopher, which is one of the many cousins of the flying squirrel and chipmunk. He was curled up in the center of a large strawstack. He had his



A flying leap.

nose between his front legs and on his breast right against his heart. The hind part of the body was rolled around his head and neck, and the tail was wound around the outside. He looked like a little bundle tied with a string.

I put him in my pocket and took him into the warm house. At first I could not see any motion of his body, but as soon as he became warm I saw signs of life. He drew a short breath, and in a moment another. Then his heart began to beat slowly, and he began to stretch his limbs, and unwind himself. By this time his heart and lungs seemed to work all right. In less than an hour he was running around the room, though he seemed somewhat bewildered.

Many animals go to sleep in this way. They are usually fat in the fall when they begin their sleep, but thin in the spring. When in this sleep they live very slowly upon the fat stored in their bodies, just as a sick person does who has no appetite. This winter sleep is called hi-ber-na-tion, and the animals which go to sleep in this way are said to hibernate. It is strange that some animals of the same family hibernate and others do not. Most of the squirrel family hibernate, but the gray and the red squirrel or chickaree do not, as I see them very often during the winter. Perhaps you can find other squirrels which are like them in this respect.

THE HERMIT AMONG ANIMALS.

Joining the woods on one side was a clover field. One September, as I was crossing this field, I saw a small, chubby animal sitting upon its haunches not more than two rods before me. At first I thought it might be a skunk, but I soon saw my mistake. This animal had a thicker body and a broader face, and was without the white stripe which extends up the middle of the face of the skunk and along the back to the tail. Then too his fur was of a grayish-red color, while the skunk's is mostly black.

I stood still to get a good view of the creature, but he soon dropped down and lay as quiet as if asleep. I moved slowly along, and when I was within three yards of him, he tumbled into his hole.

Then I called my dog, and he began at once to dig for the animal. But it was too much for him alone. So I got a spade and we soon found the old fellow and his mate. The burrow went almost directly downward four and a half feet, then it turned off horizontally for about a foot, when it became a double tunnel.

These two tunnels, after making nearly a half circle, and leading slightly upward, met again in a small, round chamber. In this was a soft bed of dry leaves and grass, which formed the lonely home of the woodchuck, the animal I had seen sitting on his haunches. When he found that he could not get away, he showed fight, but I got a noose round his body and took him home to tame him.

The woodchuck is a queer creature. Mr. Mathews says that if one could shake a red and a gray squirrel together in a bag until they became one animal with a coat neither red nor gray, then blow the thing up with a bellows into thrice its former size, jam the face together, trim down the ears, enlarge the paws, chop off half the tail, and finish by knocking just half the life out of it, one would have a fair imitation of the woodchuck.

Sleepy! I should say. To sleep was the one thing my woodchuck seemed to enjoy most, especially from September to April. If I put him into a cold room, he put his head between his front paws and rolled himself up into a bundle as round as a doughnut, and slept so soundly that I could not wake him up until I took him into a warm room. He seemed to be about half asleep even in the summer.

Woodchucks.

Although the woodchuck appears so stupid, I taught him some things easily enough. He sat on his haunches and listened to the soft playing of a violin for half an hour. He would climb into a chair and sit up looking as silly as ever an animal could. He would take rags and hay into his box. He was most comical when given a long string to pull into his den.

The woodchuck lives on herbs and grasses, but clover is his favorite diet. He does considerable damage to clover fields by the dirt he throws out in burrowing. He is a good digger, and it is from his habit of throwing out dirt that he gets his name —according to a story given by Mr. Mathews:

A long time ago all the lesser animals lived in a country ruled over by a judge—the dog. One day the rabbit, which lived next door to the marmot, complained that the latter was always throwing dirt out of his burrow into the little rabbits' eyes, and asked him to stop it. The marmot paid no attention to what the rabbit had said. At last the rabbit told the judge all about it, and he at once ordered the marmot to be more careful where he threw the dirt. This made the marmot angry, and he replied that he "*would chuck* his dirt just wherever he pleased." Ever since that time the marmot has kept the name woodchuck, and the dog is still hunting for him.

Some naturalists say that the woodchuck lays up a store of hay and leaves for the winter in a special chamber said to be sometimes seven feet in diameter. The woodchuck that I dug out had not a thing stored for food except his own fat, which literally stuffed his body.

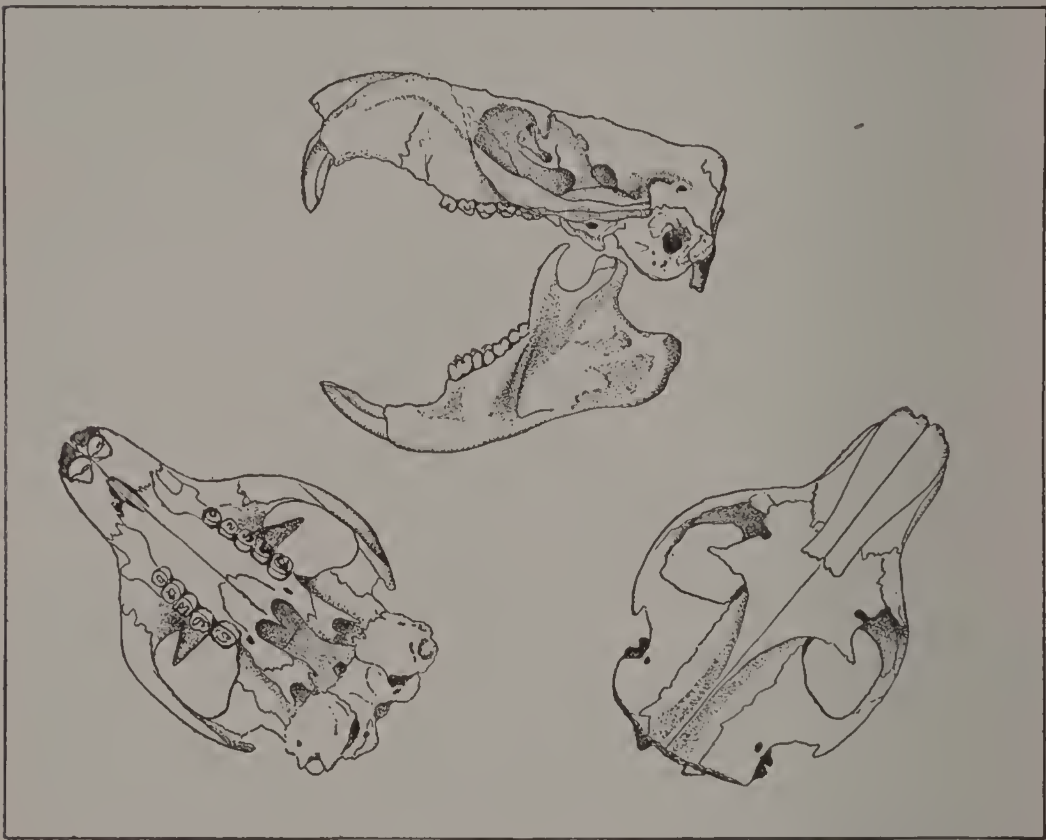
Some say that he is the longest and soundest winter sleeper of all hibernating animals, and doesn't wake up to eat any food he may have stored. The frog and the turtle do not settle down in the mud for their winter sleep until the frost has killed the insects on which they live. The black bear does not go into his winter cave before the cold winter snows compel him to. Even the flying squirrel, which is the next soundest sleeper to the woodchuck, waits until his last crop of nuts is gathered in; but the woodchuck begins his sleep in the warm days of late September, and continues it until the buds begin to swell.

Many people believe that the actions of the woodchuck, or ground-hog, as he is called, have considerable effect on the weather. If he comes out of his burrow the second day of February (Candlemas Day), and the sun shines so that he sees his shadow, he will return and delay the spring six weeks by sleeping that much longer. This, of course, is false; but he doubtless comes to try the weather, and if it is cold returns to his comparatively warm nest until he gets hungry enough to come out for food again.

The woodchuck has from four to six young ones about the latter part of April. These remain with their mother until shortly before the hibernating time, when each goes out into the world to make his own burrow and begin the hermit life of a woodchuck.

Prairie-dogs.

The prairie-dog, which is a rodent closely related to the woodchuck, lives in villages. A few years ago I drove across the plains of Dakota and passed by a very large prairie-dog village which extended over



Skull of rodent gopher. Side, bottom, and top views.

several miles. The prairie-dogs had dug over thousands of acres in making their burrows. Every rod or so throughout this village one of these little creatures was sitting up as a sentinel. When he dropped down another one immediately took his place. It was a comical sight.

RABBITS.

The chipmunk and flying squirrel have each four large front teeth like the gray squirrel I told you about. They like to gnaw with these teeth, and for that reason they are called rodents. Rodent means gnawer.

Rats, mice, and rabbits also belong to this order of animals, because they too have each four long front teeth.

Rabbits.

Besides chipmunks and flying squirrels I used to see many rabbits in this little forest, and often chased them into their burrows, which were made at the foot of trees in among the roots.

The young wild rabbits are among the most harmless, timid-looking creatures. I have often caught them and held them in my hand. Their soft, dark eyes seemed so full of fear and their little hearts beat so fast, that I could do them no harm. I caught many of the old rabbits in winter with a box-trap baited with corn.

THE QUAIL.

Sometimes a covey of quails came across my trap, and seeing the corn, went in to enjoy it. Much to their surprise, doubtless, they found themselves literally "in a box."

In the winter time quails collect in bevies and live among underbrush at the edge of the woods. They usually roost on the ground in a circle, tail to tail, and heads outward. They do not fly till you get close up to them, when they start up with a loud, whirring noise, but they soon alight and run off among the thickets. I have seen as many as twenty-five run off in that way among the brush, following their leader, and making a little path in the snow scarcely more than two inches wide.

Quails are very plain, Quakerlike birds, dressed in sober browns. Bob brightens up his costume a little with a black and white cravat.

In the spring they pair off and frequent grain fields. It is not easy to find the nest. It is cunningly hidden away in a hollow, usually in the grass on the open prairie or in a wheat field under a tuft of grain or grass which completely hides it, leaving only a door on the side. Perhaps you will find the nest full of pure, white, top-shaped eggs, fifteen or even more.

As soon as the little ones are hatched they leave the nest with the parent birds.

In the latter part of July I came upon such a family in a wheat field which had just been cut.

Bob White.

Suddenly, directly in front of me, the old quails flew off a rod or two with a whirring noise, and the little ones ran as fast as they could in every direction and hid among the stubble. I lay down flat and kept perfectly quiet to see what would follow. In a few minutes the old quails uttered low, soft calls and the little ones came out of their hiding places and ran to them.

In the spring you can often hear the quail as he sits on a fence post whistling his clear notes, "Bob White! Bob-Bob White!" Bob White has thus become his most familiar name, and I like it better than quail, don't you?

Bob White is a game bird and is very good to eat. So many of them have been trapped and shot that there are few left. They are easily tamed, and like to build their nests near farmhouses and eat with the chickens. They are very helpful to the farmers, because they eat the seeds of weeds and destroy the weevil that is found in wheat fields, besides other harmful insects.

DEER.

I MUST not forget to tell you about two deer which I came upon suddenly one winter's day. The snow was about a foot deep. I drove into the woods with a bobsled to a place where the day before a tree had been chopped down. The branches had been cut off and thrown in a heap. Beside this heap I saw the two deer lying. I had scarcely come in sight when one, which I knew to be the buck, quickly jumped up, holding his head high in the air. I was looking right between the horses, so that he could not see me until I got within about a hundred yards of him. By this time the doe, too, had risen, and both bounded off with such easy, graceful leaps, that it seemed to me it was no trouble at all to them to get over the ground.

Head of deer.

Deer are timid animals. When danger is near they depend upon their swiftness of foot. For this reason they are always on the alert. Three of their senses—hearing, seeing, and smelling—are well developed. Their ears are placed on the side of the head and turn backwards and are sure to hear the slightest sound of approaching footsteps. Their large bright eyes detect every movement within sight. It is impossible to approach them from the windward side, as their keen sense of smell quickly warns them of the presence of an enemy.

When a number of deer are together, one or more of them act as sentinels. They hold their heads up high, sniff the air, and look around in all directions. They seem to know that the safety of the herd depends upon them.

Antelope, which are very much like deer, though smaller, are even more alert. It is almost impossible to get near them. The hunter can approach them only where he can completely conceal himself in bushes or behind rocks.

Pair of deer.

A hunter one time saw a herd feeding on a hill in an open place. An old buck was standing guard, turning his head now this way and now that, so that

Virginian deer.

the hunter had to lie flat on the ground and drag himself along in the grass, hiding behind little lumps and ant-hills. He had to move so slowly and carefully, that it took him three hours to move three hundred yards.

I believe the antelope has the most beautiful eye of all animals. It is a soft dark brown, easily taken for black. He has small, dainty feet, with long, black, shiny hoofs.

Antlers peeling.

One of the most interesting things about the deer family is their antlers. Only the males have them, and they shed them once a year. About the time the trees begin to bud the antlers begin to grow. At first a small bony knob, covered with velvety skin, appears on each side of the forehead. When this knob is a few inches long it divides into two parts and forms the first branch. Thus it grows on, adding branches and becoming harder all the time until the antlers are well grown, which is about the end of August. They are a bony growth, covered with a soft, velvety skin. Then this skin begins to dry and to peel off in strips. The buck wears it off by rubbing his antlers against trees and brush. The bone,

Prong-horn.

(From photograph, and United States Natural History Government Reports.)

though at first white, turns a dirty gray and becomes hard and smooth. In December the antlers fall off and the skin grows over the scar.

I believe that a buck adds one branch to his antlers every year except the first year. If that is true, we can tell how old a buck is by adding one to the number of branches of his antlers.

The antelope has no antlers; he has true hollow horns like the cow's, though not of the same shape. The horns have a bony center, which grows out from the top of the head. This bony core is covered with a horny shell. Every year a thin skin grows between this shell and the core. This skin begins to

Deer's antlers.

harden and becomes bony, first at the point, then more and more toward the head, until the new horn is formed and forces the old one off. Only the American antelope grows new horns every year; other species retain the horns during the life of the animal.

In November the bucks, or male deer, are very

Doe and fawns.

jealous of each other, and often have long and terrible fights. Sometimes the antlers of old bucks become locked so that the deer are unable to separate and either starve or are torn to pieces by wolves or other wild animals.

The young of the deer are born in May. There are usually two, and they are called fawns. It is a most interesting sight to see a pair of fawns gambol

Bucks fighting.

and play. They are quite as active as lambs, but very much more graceful. Then their bright eyes are always looking around to see what things are. When scared they leap with wonderful grace and swiftness. They eat almost everything that comes in their way. It is reported that a fawn once ate a package of tobacco, but he died the next day.

THE WOLF.

In a cave near the west end of the forest an old wolf made his home. Whenever he was hungry he took a trip to the pasture fields near by to look after the sheep, much to their sorrow but greatly to his own satisfaction. He killed several of our sheep. He bit the sheep in the throat and tore the breast open to get at the vitals; the rest he left. We often watched for him and chased him, but it was three years before he was hunted down by one of the neighbors who had lost several sheep.

The wolf looks like a dog. His body is rather long and the muzzle is more pointed than that of most dogs. A wolf's tracks may be distinguished from those of the dog, by the fact that the wolf sets his feet behind each other, while the dog places one hind foot a little out of line as he trots along.

It is claimed by naturalists that the dog is descended from tamed wolves. This may be so; but as the dog has been with man throughout the ages of history, may it not be possible that wolves have descended from dogs that were left to run wild? What do you think about this?

In wild regions of the world wolves are still found in great numbers, and sometimes even become

Coyotes—American prairie wolves.

dangerous to travelers. When they are very hungry they will attack man. Travelers shudder to hear the howling of a pack of wolves. It is a very dismal sound, and one never to be forgotten.

The dog and all other flesh-eating animals have pointed, jagged teeth, not suitable for grinding but for tearing the food. This order of animals is called carnivora (*carnis*, flesh, and *vora*, eaters). It includes the dog family, the cat family, bears, weasels, and others.

SNAKES.

Near the wolf's den in the forest was a "sink-hole"—that is, a rift in the rocks below the surface, into which the brook ran. All the soil that had been on top of the rocks was washed down by the brook. This made the hole funnel-shaped.

About three miles farther down the valley a stream of water came bubbling up between the rocks, called "Big Spring." It is generally supposed that this water was the brook which disappeared in the sink-hole and flowed under ground between rocks for that distance. Around the Big Spring, on both sides of the valley, were rugged rocks and high cliffs. In these rocks could be found many rifts and small caves. One of these caves was known as "Rattle-snake Den." One beautiful summer day a number of the boys went to this cave with their guns and killed twenty-three rattlesnakes that varied from a foot and a half to about six feet in length.

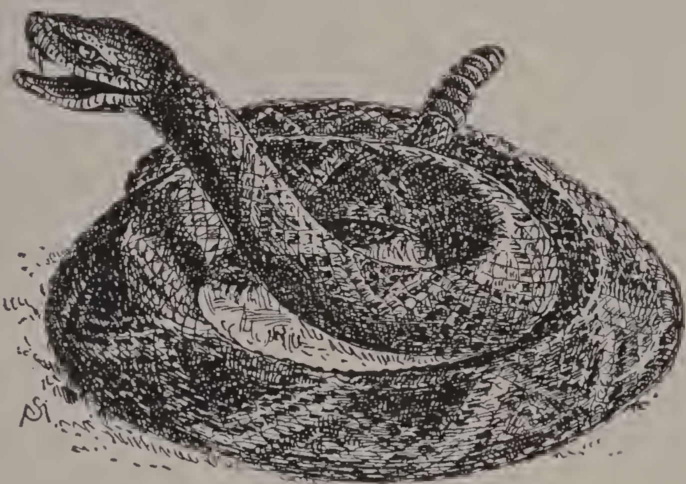
How does a snake get over the ground? The bird has wings, the fish has fins, and most animals have legs on which to move. But what has the snake?

The snake has a great many ribs which are fastened to the backbone. The lower ends of the ribs extend to the skin on the under side. They can be moved at will by the snake.

Rattlesnake.

If you will put yourself into a big bag and tie it at the neck, then get down on your hands and knees, imagine your arms and thighs ribs, and creep along, you will get some idea of how a snake moves. It really walks, as it were, on the ends of the ribs. The skin, which moves with the ribs, has scales that help the snake to push itself along, by catching hold of the objects over which it passes. It finds great difficulty in getting over a smooth glassy surface.

When a snake moves it bends into curves sidewise and not up and down, as is often seen in draw-



Coiled for a spring.

ings. It can keep up its swift motion only a short distance, as it gets tired very quickly. Snakes move about very little except to get food or escape from enemies.

The rattlesnake is copper-colored; the upper part and sides are covered with dark-gray, irregular blotches. Like all poisonous snakes, it has a flat head and very few teeth. In the front part of the upper jaw it has two fangs which it can conceal in the gums. A poison sac just below the eye is connected with these fangs by a tiny tube which passes through them to their points. When a snake becomes angry it pushes the fangs forward and the pressure caused by biting forces the poison out into the wound.

One time when I was out in the prairie barefooted, I passed within three feet of a rattlesnake. I saw it just as it began to rattle. It was coiled up with its head raised in the center of the coil ready to spring upon me. I jumped sideways farther than I had ever jumped before.

The most curious thing about the rattlesnake is the rattles at the end of its tail. They are hard, horny, globular joints, loosely connected. When excited the snake shakes its tail violently, and the rattle may be heard at some distance.

Every time the snake sloughs its skin it adds a new joint to the rattle between the tail and the rattles already formed, so that the oldest rattle is always at the end. Sometimes the end joints wear off, so that the number of rattles is not always an indication of the age of the snake.

SOME THINGS ABOUT SOIL.

The earth on which we live is an immense rocky ball. In many places we can see the rocks at the surface. But large areas are covered with ground or soil, and still larger areas are covered with water.

If we dig a hole deep enough anywhere in the soil, we shall come to rocks. We find rocks even under the oceans. Was there ever a time when there was no soil anywhere on this rocky ball? Was there ever a time when there was no water on it? We shall have to wait a while before we can answer these questions.

Have you ever thought what would happen if every bit of soil should suddenly be taken away? There would be no trees, no flowers, no grass, no weeds, not a single green thing, and, of course, all animals that live on plants would die, neither would the animals which live on other animals have anything to live upon. In short, there would be no life on the earth at all. Was there ever such a time? Thus we see the great importance of the soil.

SAND AND PLANT MATTER.

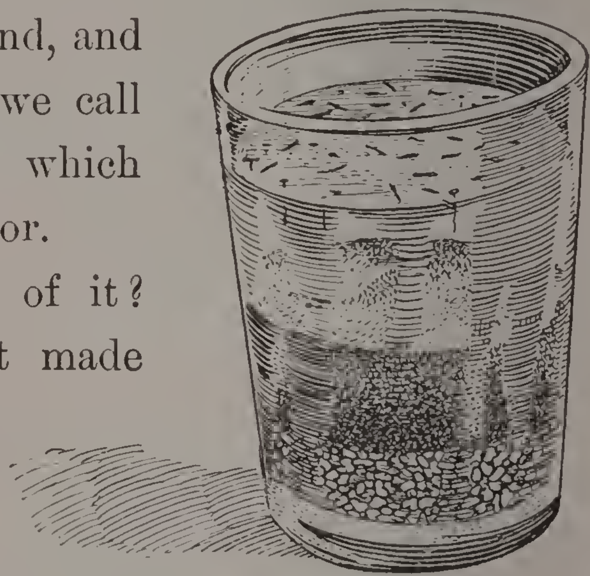
Everyone knows what we mean when we speak of the ground or soil, but few ever stop to think what it is made of.

I asked myself that question, and at once set to work to find an answer to it. This is what I did: I went into the garden and took a cupful of sandy soil and put it into a basin. Then I poured water on it, and rubbed it between my hands, until all the lumps in it had disappeared.

What did I see? A number of small roots and bits of leaves floated on the water. In fact, the surface of the water was covered with them.

I slowly poured water into one side of the dish, allowing the dirty water to run off at the other side into a large pan, and at the same time stirring the contents gently.

Finally I had left in the basin clear sand. There was enough to equal one third of a cupful. Thus I found two of the things of which soil is made—sand, and decayed plants which we call vegetable mold, and which give the soil a dark color.



Soil settlings.

What was the rest of it? It was something that made the water dirty. I set the pan which contained this dirty water in the warm sun until all the water had evaporated. There was a thick coating of mud in the bottom of the pan. When it was thoroughly dry it became dust. I took some of this dust and looked at it through a microscope. I found that part of the little dust particles were fine grains that looked like sand, and I concluded that they were grains of sand so small that they would float in water when it was stirred. When I washed the soil, the larger grains only of sand sank to the bottom, while the finer sand floated in the water and was carried over into the pan. Thus I found that most of the soil which I examined was sand, and that a part, if not all, of the rest was decayed leaves, stems, and roots.

Then I took a cupful of clay soil, and washed it as I had done the sandy soil. I found a little sand in it and a few bits of leaves and stems, but most of it was like paste. It felt smooth and soapy. I did not know what it was.

WATER, PLANT, AND MINERAL MATTER.

I TOOK a piece of sheet iron and made a small pan. It weighed four and a half ounces. I got some black garden soil, which I took out six inches below the surface. I put some of the soil in the pan. The pan and the soil together weighed sixteen and a half ounces, making twelve ounces of soil. I dried the soil thoroughly on the stove and weighed it again. I found that it had lost two ounces, or one sixth of its weight. The loss of course was water. I made the test at the end of a dry spell or the loss would have been greater.

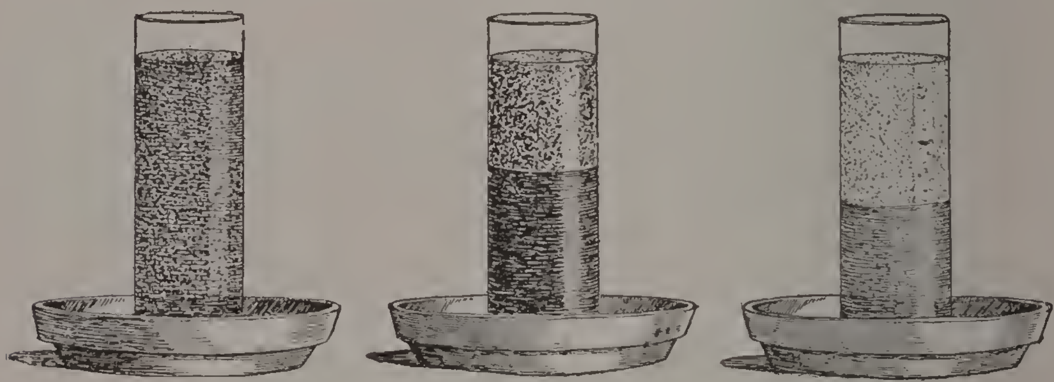
Then I set the pan on some red-hot coal for several hours. On weighing it I found that the soil had lost another ounce. All bits of leaves, stems, and roots had been burned.

The experiment showed that one twelfth of this garden soil was plant matter, one sixth was water, and the rest was mineral matter—that is, material which came from rocks.

CLAY, LOAM, AND SANDY SOIL.

I COLLECTED three kinds of soil. One was yellow clay; another was a heavy, black soil which I shall call loam; the third was a soil composed mostly of sand.

After drying and pulverizing these soils, I put an equal quantity of each into a glass chimney, which I set into a saucer, as may be seen from the picture.



Three lamp chimneys, containing different sorts of soil, showing the comparative rate of progress made by the water rising in each.

Into these saucers I poured half as much water as there was soil in the chimneys. I could see, through the glass, how rapidly the water rose in the soil in each chimney.

When the water had risen to the top of the sandy soil, it was only two thirds of the way up in the loam and only half way up in the clay.

Which do you think lost most water in two weeks? You will say the sandy soil, because the water rose fastest in it, and therefore evaporated fastest at the surface. That would be correct; for I found by weighing them that the sandy soil had lost about two ounces of water, the loam an ounce and a half, and the clay only a little over an ounce. The clay was quite moist in the lower part of the chimney but dry and hard on the top, while the loam was almost as damp at the top of the chimney as it was at the bottom.

Then after adding four ounces of water to each saucer, I planted five seeds in each chimney—corn, bean, pea, morning-glory, and sunflower—and awaited the results.

On the sixth day I noticed two seeds coming up in the sandy soil, but nothing was to be seen in the other soils until the eighth day, when three appeared in the clay. Those in the loam did not appear until the ninth day. Some of the seeds in all the chimneys failed to come up. I added a little water, the same amount to each chimney, every second day.

Those in the sandy soil grew most rapidly, but soon looked thin and wilted; those in the clay came up next, but grew very slowly and remained short; while those in the loam came up last, grew slowly at first and then rapidly, becoming taller

The development of seeds planted in the different kinds of soil in the lamp chimneys. From photograph taken twenty-one days after the seeds were planted.

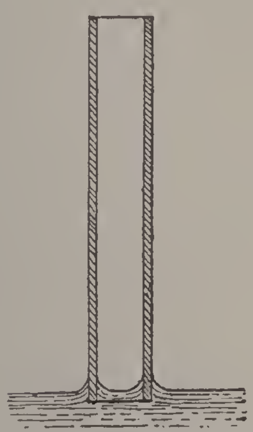
and healthier-looking plants than those in the other two soils. The picture was taken twenty-one days after the seeds were planted.

The plants had long, thin roots, covered with tiny hair rootlets. I could see them distinctly through the glass, especially in the clay soil.

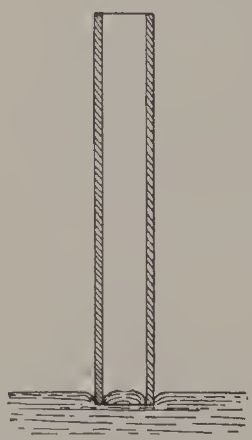
CAPILLARY ATTRACTION.

As I watched the water rise in the soil inside the chimneys, I asked myself what made it rise. "Oh, that is easy," you may say. "The soil sucks the water up like a sponge." That may be true, but it does not explain anything.

I have here a little cupful of quicksilver or mercury and another of water. If I put a stick into



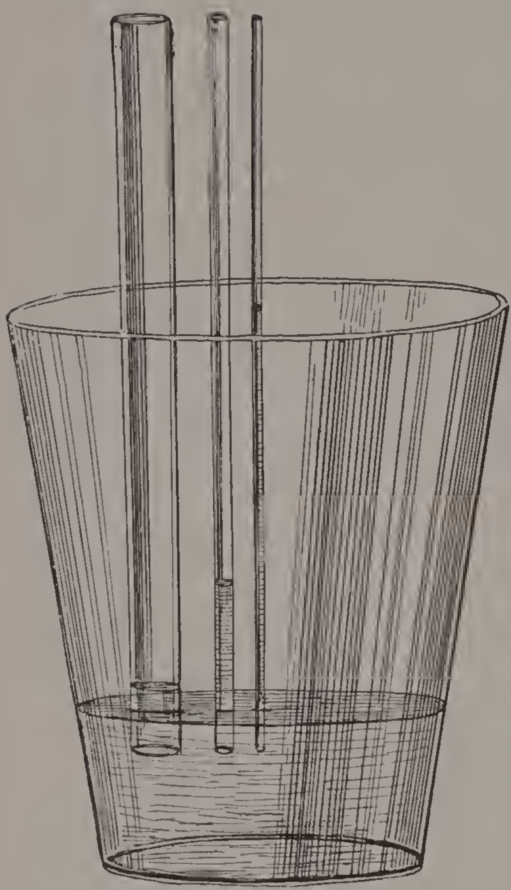
Glass tube in water.



Glass tube in mercury.

the mercury and one in the water, one will be perfectly clean and dry and the other will be wet. The mercury does not stick to wood, but water does.

If I take a glass tube instead of the stick the result will be the same. If I should take a gold ring or a gold pen, and put it into the mercury, some of the mercury would at once stick to the gold, and so well that it would be impossible to rub it off. We say that mercury adheres to gold, but does not adhere to glass and wood. Water adheres to nearly everything. We say there is adhesion between glass and water and no adhesion between glass and mercury. There is adhesion between chalk and the blackboard, between paint and wood, between varnish and glass.



Tubes of different sizes in water, showing the comparative height at which water will rise in tubes of different diameter by force of capillary attraction.

Particles of the same substance are held together by a force called cohesion. We can not easily break a stone apart because there is much cohesion between the particles. Water has little cohesion. Cohesion means sticking together; adhesion, sticking to.

The picture shows a glass tube put in mercury and one in water. You will see the mercury is depressed around the glass tube and inside of it, but the water has climbed up on the tube both inside and out. Now the finer the tube, the higher the water will climb, as you see in the picture of the three tubes.

It seems that the little particles of water brace each other up inside of the tube. This tendency which some liquids have to climb up in small tubes is called *cap-ill-ary* attraction (*capillus* means hair). Long, fine tubes are called capillary tubes.

If one end of a towel is laid in water, the whole towel will become wet by and by, because the threads of the cloth act like little tubes. So the spaces between the particles of soil are like fine tubes, and the closer the soil is packed together the smaller these air spaces will be, and the faster the moisture will rise to the top and evaporate. If you dig down a foot in a plowed field and then in a hard roadway, at which place will the soil be dryer?

HOW SOIL IS MADE.

As has already been said, soil consists chiefly of sand and other decomposed rock material. We have traced the history of a pebble, how it was broken off from a large rock, pushed along and rolled over and over by the water. What became of the material rubbed off? It was carried along by the water until


Formation of talus or heap of stones at the foot of a disintegrating cliff.

it was dropped or deposited, together with other material, in a quiet place along the bank or on the bed of the stream. There are rivers which have brought down tons and tons of soil made from rocks.

Most rocks are of two kinds of material. Hard, rocky grains which can not be dissolved by water are held together by grains which water can dissolve. Our common mortar is a good example. Sand, which is the insoluble part, is held together by lime, which is soluble in water. When such rocks are exposed to the air, the moisture in the air slowly dissolves the soluble part, and the rock falls to pieces. The insoluble fragments are finally worn down to dust in the same manner as pebbles are.

In Mississippi and Alabama I saw soil formation that was very interesting. On the surface was reddish clay. Below that was the same material a little darker and harder. Still deeper down was what looked like thin layers of red rock, but it was so brittle that it could easily be crumbled into small pieces. Under this was a layer of rock only slightly softened, and still farther down I found hard solid rock.

Here was a good illustration of rock changing to soil. It showed all the stages from solid rock to perfect soil. The rotting process, of course, goes on very slowly. We may see something like that in many parts of this country. In most stone quarries the upper layers of rock are much more brittle than those deeper down.

In the picture you can see a heap of small stones lying against the cliff. How did they get there? They are evidently fragments from the rocks above, and were broken off by some force. One day early in spring I stood on a large cliff, when an immense rock fell from the upper part of the cliff. I asked myself what made it fall.

I saw the cracks and seams in the different layers or strata of rock. The water filled these seams, and during the winter froze solid. You have seen many instances of how water increases its bulk in freezing, and what force it has to break the strongest bottle or pail. So I think that the frost forced the rock slightly from its place, and when the warm spring rains loosened its hold, the rock tumbled over the edge of the cliff.

You can also see that the rocks near the top are not so closely packed and the corners are rounded. The rocks on the face of the cliff are smooth and rounded too. I think the wind had something to do with that. Dust and sand blown against the cliff must wear the exposed rocks off. Often the window-panes on the wind side of old houses near the sea-shore are grooved and worn wavy by the sand blown against them.

Thus we see that water, frost, and atmosphere are makers of soil. Each does a part, but water is doubtless the most important agent in the formation of soil.

EROSION.

The soil that is made on the hills is continually being carried down the slopes by water and deposited in the valleys. I have often noticed how much the rain accomplishes in this way in railroad cuts and piles of dirt. The water forms little rills, and these rills form larger ones, cutting channels for themselves which become deeper year by year. At first their

Banks of soil eroded by rains.

banks are steep. Then they become rounded, forming slopes. These slopes are ever becoming longer. In this manner most of our hills and valleys were formed.

When the stream comes down a mountain and flows through a country which has little rain, the banks always remain steep, and, instead of broad valleys and long slopes, we have what are called cañons.

One day I put some soil into a glass jar, and then poured water on it and stirred it well. As soon as the water became quiet, soil began to settle on the bottom. The coarse sand and pebbles settled first, then the finer sand, and lastly the finest stuff, which formed a layer of mud on the sand.

Some of the soil that is brought down the slopes is washed into creeks and rivers, and by them carried down toward the sea. The swifter the current the more soil the stream can carry. As soon as the current becomes less, as it always does near the mouth of the river, or when it flows over its banks into lowlands, it deposits some of the soil.

The coarser parts settle first, while the finer material is carried on in the water even to the sea; or, when the river overflows its banks, some of the soil is deposited on the bottom land. Such soil is called silt or sediment.

The Nile overflows its banks every year and deposits a thin layer of mud on the adjoining land, and thus it not only thoroughly soaks the soil, but makes it fertile. Large quantities of silt are carried down from our hills and slopes by the Mississippi and deposited in the Gulf at the mouth of the river. In this way the Gulf is being gradually filled up and the river made longer, more than three hundred miles, it is claimed.

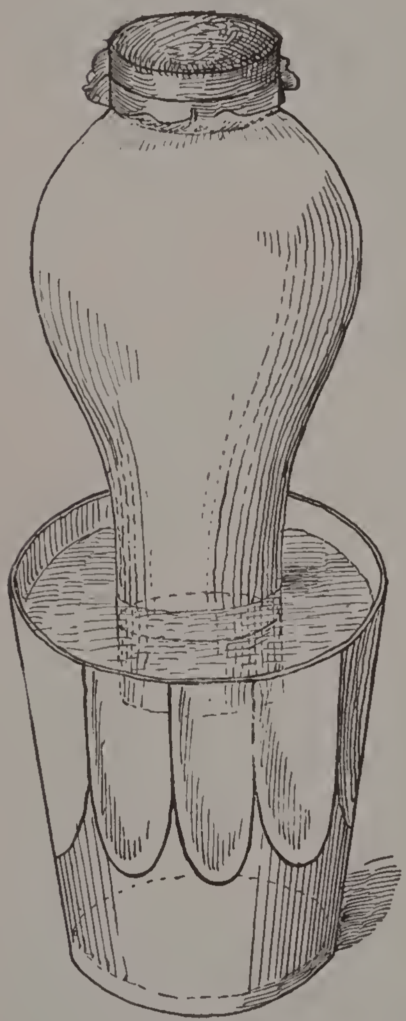
Delta of the Mississippi.

AIR IN EVERYTHING.

I WILL now tell you some things about the air. I will take a glass lamp chimney and put it down vertically into the water in the dish.

The water rises in the chimney in the inside as far as it does on the outside. Now I'll tie a sheet of rubber over one end of the chimney and again put it down in the water. Ah! the water does not rise in the inside as far as on the outside. Who can tell why? There must be something in the chimney that keeps the water from rising. It presses the rubber up.

Let us see what will happen if I make a pinhole in the rubber covering. Now feel the air coming out of the pinhole. That tells the story. There was air in the chimney, and as long as it could not get out the water could not get in.



Lamp chimney with sheet of rubber tied over one end.

If I put the palm of my hand over the chimney, instead of the rubber, I can feel the air pressing against my hand.

Suppose I take an empty glass and press the open end down into a basin of water. The water can not enter; but if I tip the glass far enough, so that the air is forced out in bubbles, the water enters.

If I take an empty bottle and press it down into the water, open end upward, the water will force the air out in bubbles.

Thus we see that water and air can not occupy the same space at the same time. We notice, too, that a bottle which we call empty is not empty, but is full of air.

Then I pressed the chimney closed at one end with rubber down again into the water. I noticed that a little water entered it, and the further I pressed it down the more water entered. I think the water pressed the air together. This shows that air is compressible.


Experiment showing that air and water can not occupy the same space.

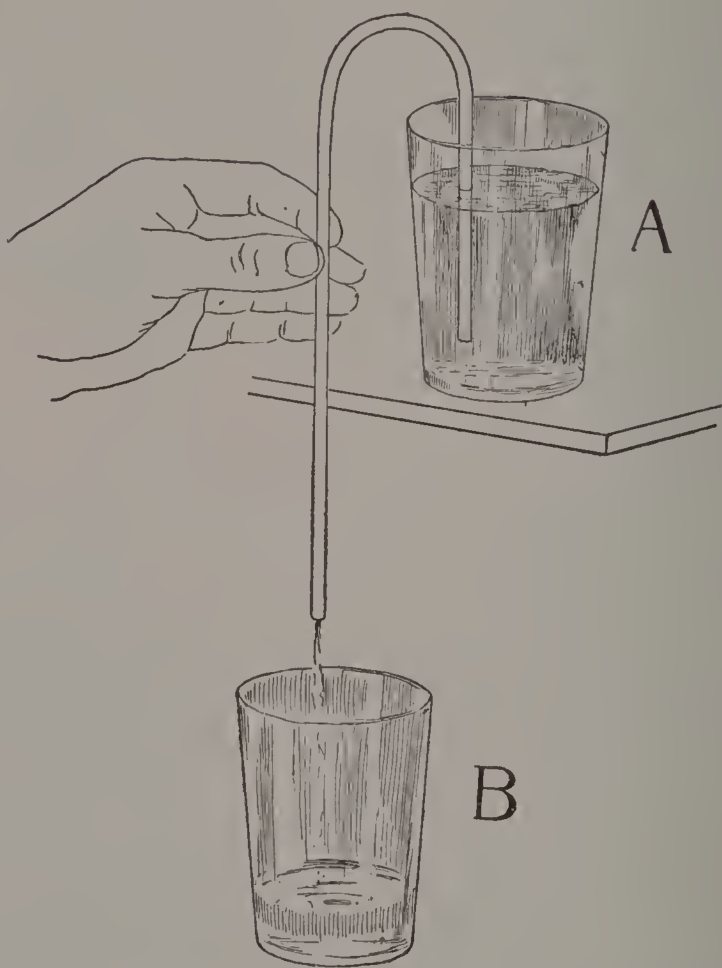
If I raise the chimney so that the water pressure is less, the air expands again and pushes part of the water out. So we see that air is elastic. The more we compress air the more elastic it is.

We may pump air into a bicycle tire until the air in it is so compressed that it makes the tire almost as hard as stone. Then if we let half of the air out, the rest of it will fill the tire, because it is elastic.

The above experiments show that air occupies space; that it may be compressed until it becomes dense; and that when the pressure is taken off, it is so elastic that the particles again separate.

AIR HAS WEIGHT.

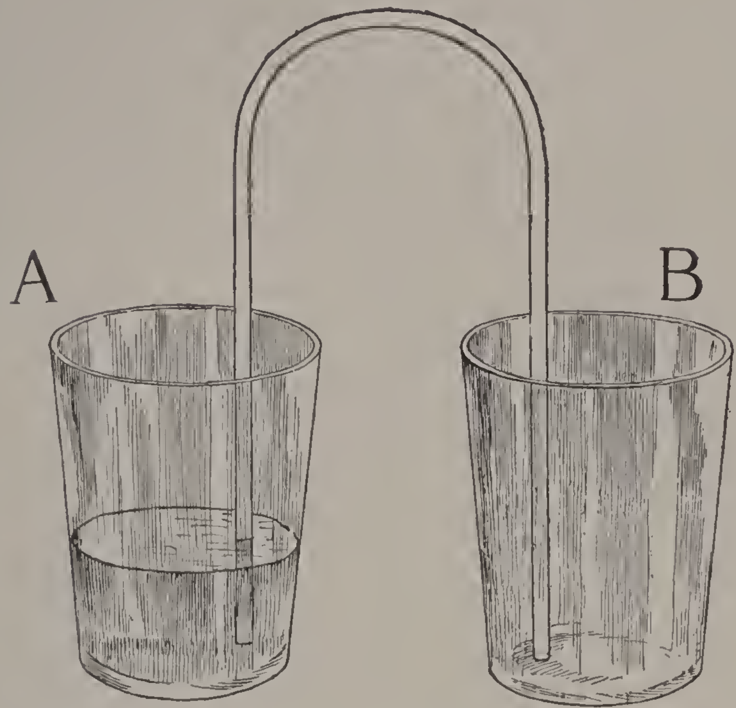
I LAID the chimney, with the rubber covering over one end, into a basin of water until it was full. Then I set it up, taking care that the open end remained



Bent tube, one arm longer than the other, forming a siphon that empties glass *A* into glass *B*.

under water. Now the water was up to the rubber in the chimney, six inches higher than it was in the basin. What kept the water up in the chimney?

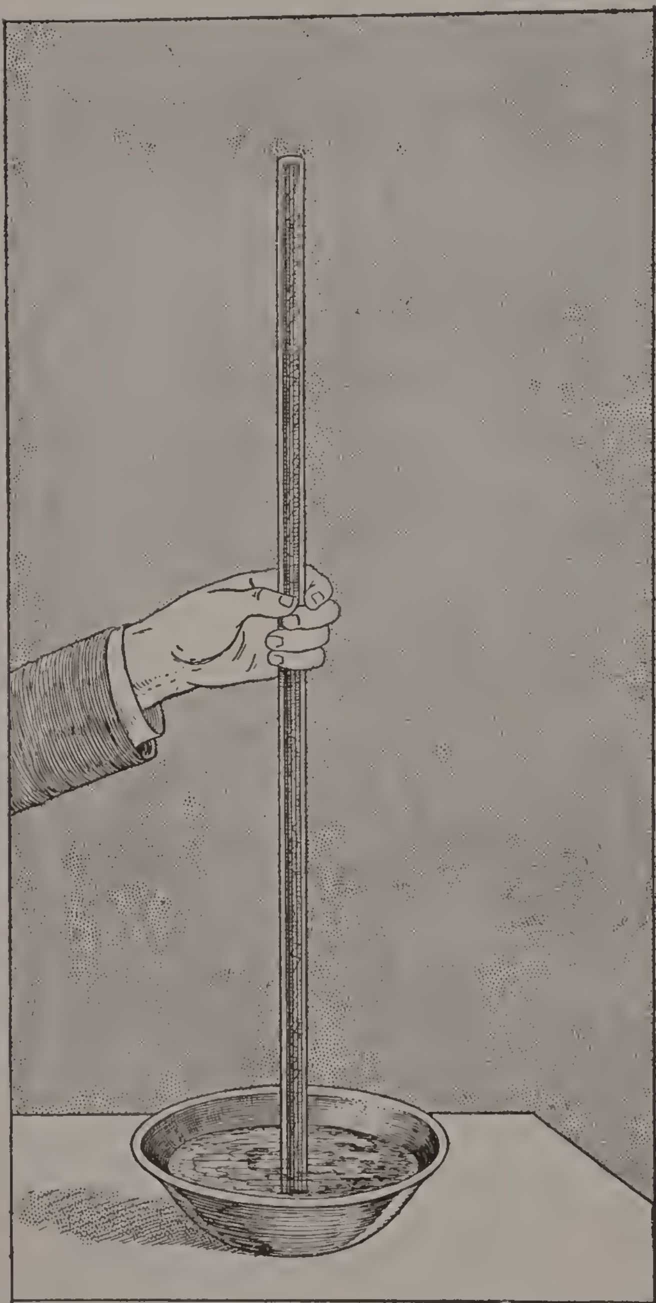
As soon as I made a pinhole in the rubber, the water slowly fell in the chimney until it was no



Bent tube with equal arms. Water does not flow from one glass to the other.

higher inside than out. So I think that at first there was no air in the chimney pressing down on the water, but that there was air pressing on the water in the basin, and this pressure of the air kept the water up in the chimney, where there was no pressure.

The siphon is another illustration of air pressure. As you see in the picture, the arm outside of the glass is lower than the water in the glass. Now, if the air is sucked out of the tube, the water will flow through the siphon until the glass is empty. What makes the water flow over the bend on the siphon? I think the water in the long arm, being heavier than that in the short arm, falls out of the tube. As it falls it creates a vacuum in the highest part. The air pressure in glass *A* forces the water up to fill the vacuum, and thus the flow is continued. If the outer arm is raised to the level of the water, the weight of the water in both arms is equal and there is no flow either way. But if the arm is raised higher, the water will flow from *B* to *A*.



Water, standing four feet high in a tube of that length, balanced by the pressure of the atmosphere.

Can you empty a tub or a barrel with a rubber tube in this way?

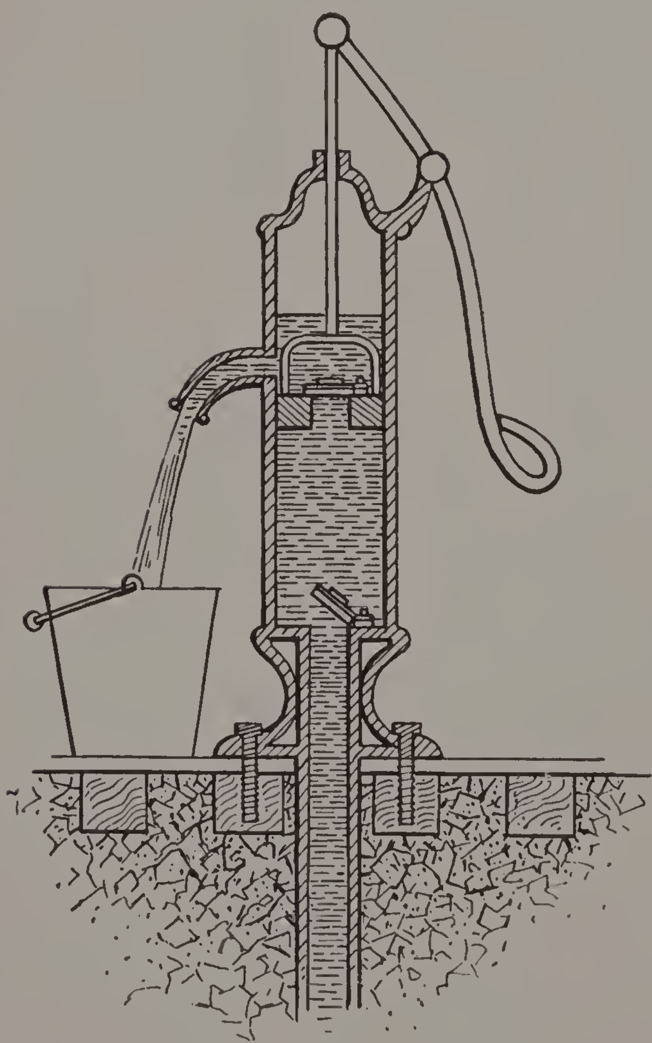
Then I took a glass tube four feet long, put a rubber cork tightly in one end, and poured it full of water. Placing my thumb on the open end to keep the water in and the air out, I inverted the tube in the basin of water. The water stood four feet high. This showed me that the pressure of the air on the water in the basin was enough to support a column of water four feet high. The least bit of air let in at the top would make the water drop in the tube.

Air lifted out of a tube is replaced by water.

Then I took a rubber cork which just fitted into a tube and forced a long straight wire through the center of it, and bent the end a little so that it would not pull out of the cork. I put the wire through the tube, and setting the lower end of the tube in the water, I pulled the cork up in the tube by means of the wire. As the rubber cork lifted the air out of the tube, the water rose in it. If my tube had been long enough, how high do you think the water would have risen in it?

It would have risen until the weight of the water in the tube was equal to the air pressure. It has been found that water will rise about thirty-three feet in pump tubes.

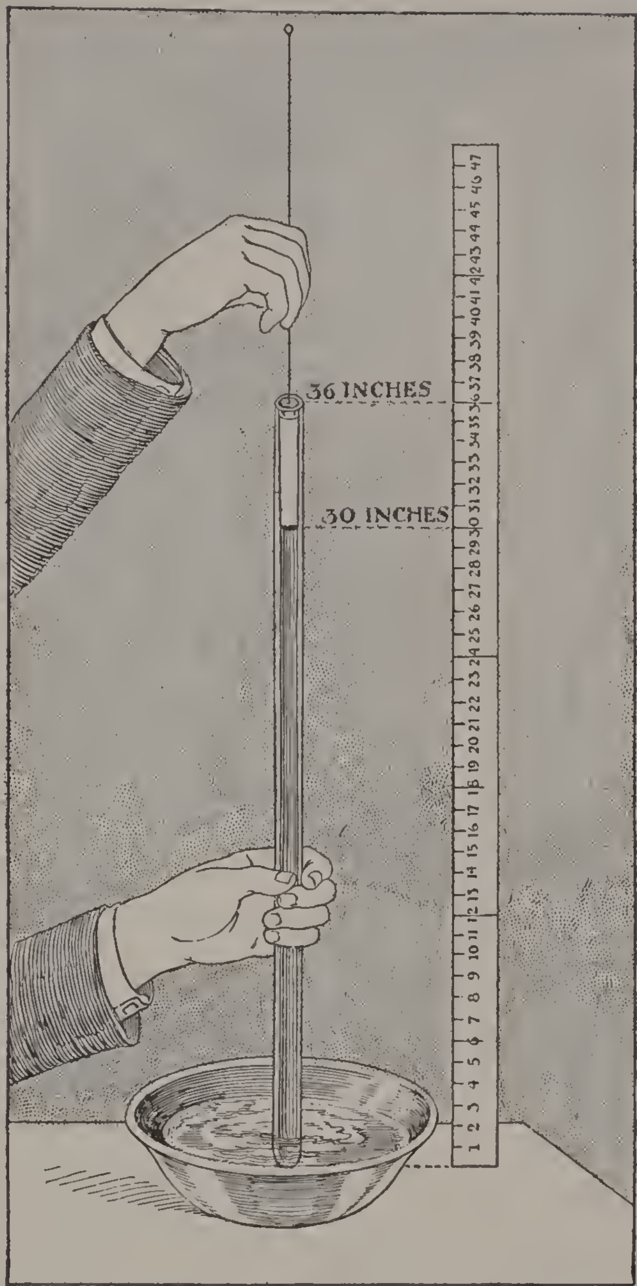
There are two valves, often called "suckers," in a pump tube. When the piston is lifted, the valve in it is closed by air pressing upon it from above. A vacuum is formed below it, and as it moves up the water rushes up from below through the second valve to fill the vacuum. Then when the piston is lowered, the lower valve closes and the water above it passes up through the valve in the piston.



Pump, showing action of valves.

When the piston is raised again, the water above is lifted with it, and again a vacuum is formed below as before.

Next, I took a tube, three feet long and sealed at one end, and instead of water I used mercury, as you see in the picture. I found that the mercury would stand in the tube only thirty inches above the mercury in the cup, leaving an empty space or vacuum of six inches at the top of the tube.



The height at which a column of mercury balances the pressure of the atmosphere.

Then I weighed the mercury in the tube, and found it to be three and three fourths ounces. Now, the opening in the tube was equal to one eighth of an inch square. A square inch is sixty-four times as large as that. A column of mercury one inch square and thirty inches high, then, would weigh sixty-four times three and three fourths ounces, which equals two hundred and forty ounces, or fifteen pounds. Therefore the pressure of the air must be equal to fifteen pounds on every square inch of surface. If the air had no weight, it would have no pressure.

Naturalists have tried this experiment on mountains, and found that the mercury would not rise thirty inches. The higher the mountain, the lower the column of mercury, and therefore the less the air pressure.

How may this difference be explained? If we pile a number of books one on top of the other and wish to lift the lowest book, we have to lift not only its own weight, but the weight of all those above it. So it is with the air. The lowest stratum has all the air above it resting upon it. Then, too, since air is compressible and elastic, there is more air to the cubic foot in the valley than on the mountain.

THE ATMOSPHERE.

When we speak of the air as a whole, we say the atmosphere. The atmosphere is a great ocean of air all around the earth. It is probably not more than fifty miles deep. We live in the bottom of this ocean. We are not able to live comfortably more than about two miles above sea level, as the air becomes too rare.

By making many experiments with the mercury tube, naturalists found out that in ascending mountains the mercury falls one inch for every eight hundred seventy-five feet ascent. Of course, if the mercury stood only twenty-nine inches in the tube, the air pressure would be only twenty-nine thirtieths of fifteen pounds, or fourteen and a half pounds. Now, if we were on a mountain and found that the mercury stood twenty inches high in the tube, we would know that we were ten times eight hundred seventy-five feet above the sea level and that the air pressure was only two thirds of fifteen pounds.

By this method scientists have been able to find the height of different mountains. It is also found by experiment that the air-pressure at the same place is not the same on different days. On a fair day the mercury stands higher than it does on a foul day. Sometimes the air is so light that the smoke will fall instead of rise. This fact enables us to tell by means of the mercury tube what kind of weather we shall have a day or so in advance.

When this cup of mercury with its tube is fastened to a board on which the scale of inches is marked, it is called a barometer. Travelers now use a barometer made in the shape of a large watch or small clock. A spring takes the place of the mercury. It is much more convenient than the mercury barometer.

MATTER.

Everything that we can hear, or see, or taste, or smell, or touch is matter. The rocks are matter; the softest sound is matter; the most delicious perfume is matter; our bodies are matter, and we are touched on all sides by matter, which we perceive by our senses.

Matter has weight. Scientists have made experiments, and by means of them are able to tell us the weight of the sun, or of a mouthful of air.

Matter can be divided. Every boy knows that he can cut his apple in two and give his sister half of it, if he wants to do so. He can cut his half again and then the quarter, then the eighth, and so on, until the pieces are so small that the sharpest knife will not cut them again. If you want to be a scientist you must imagine each of the smallest pieces of the apple still farther divided until it is so small that no smaller piece of apple could exist.

Red ink is made from finely powdered coloring matter. If one grain of this powder is thrown into a cup of water it will color the whole of it. The grain must be very finely divided in order to distribute itself through so much water.

A drop of some of the perfumes will scent the whole house for days.

The smallest bit of matter that can exist by itself is called a molecule (*mole*, mass; and *cule*, little), which means a little mass.

We know of matter in three forms. A piece of stone, or of bread, or of candy is matter in solid form. Water, oil, and the like, are matter in liquid form. Air, lighting-gas, and the like, are matter in gaseous form. Liquids and gases are also known as fluids.

Solids, generally speaking, do not easily change their shape, but liquids take the shape of the vessel that contains them. In gases the molecules separate from each other, so that a single cubic foot of air would fill a whole room if there were no other air in the room.

SOUND.

It was now late in the fall; the days had shortened considerably, and the wind had become chilly, even cold. My little friends, Willie and Tom, came to visit me often. They also brought with them Tom's little sister Amy. As these children had lived out of doors most of their lives and had sharp eyes, they were always sure to ask many questions.

One frosty morning they made me a call, and, as soon as they were seated, Willie began: "This morning I heard the large bell in the church as I never heard it before. The sound came to my ears in waves, as it seemed to me. When the man stopped ringing it the tône was like this, –ng–ng–ng–g–g. What is it that comes to my ears? What is sound? Is the

Vibrations of the air, caused by ringing a bell, as they would appear if they were made visible.

sound that I hear a part of the bell, or is it a part of the clapper? It seems to me it can be neither, for then they would soon wear out."

Might there not be something in the bell which is given out when the clapper makes it vibrate, just as perfume is given out by flowers? We read about perfumes which have for over two thousand years given out their odor and, so far as can be noticed, do not become less. If this is true of perfumes, may it not be true of bells? However, I do not believe such is the true explanation. I think the bell when struck trembles or vibrates and makes the air too vibrate in such a way that it produces impressions upon the ear which we call sound.

Let me illustrate my idea of how sound is produced. Here is a basin of water. Notice the effect of letting drops fall upon it. Little waves move out in circles to the edge of the basin.

Perhaps you remember that when you throw a stone into a pond the wave circles move outward till they reach the shore. As the stone strikes the pond it pushes the water aside, forming a wave. When the stone sinks, the water rolls back, and thus begins to move up and down starting the wave motion.

"I think I know now," interrupted Tom. "The bell makes waves in the air, and when these waves strike our ears we call them sound."

That was a bright answer, Tom, and quite correct too. But in the pond, as the wave moves toward the shore, it makes the water bob up and down. This cannot be the case in air.

Have you ever seen a long freight train start up?

When the engine gives a jerk it hitches up the first car, and that car the second, and so on to the last car. The jerk or sudden pull of the engine runs quickly along the whole line of cars. Each car is jerked a little toward the engine, and then it springs back again as far as the coupling will permit.

You must think of the air as being made up of very small elastic balls, so small that they can never be seen. When the big hammer strikes the bell rim it makes it vibrate. The rim strikes against the little air balls all around the bell, and these air balls strike against other air balls near them, and bound back like the freight cars I spoke of.

In this way the vibration is carried along through the air more and more slowly until its force is used up. The air balls move in the same direction in which the wave moves, and not perpendicular to it as the water particles do, so that instead of having high and low points, the air is crowded together at some points and farther apart at others; or, as we would say in book language, is condensed in some places and rarefied in others, as the picture shows.

If we suspend a little alarm clock in a bell jar and then pump the air out as far as it is possible, we cannot hear the alarm when it goes off. If we allow a little air to rush into the vacuum we can hear the alarm faintly. The more air we let in the more distinct the sound will be. This shows that sound will not pass through a vacuum. Scientists believe that the moon has no atmosphere. If that is true there is no sound there—nothing but eternal silence.

"What is a vacuum?" inquired Amy.

A vacuum is a place where there is no liquid, gaseous, or solid matter, not even air.

VELOCITY OF SOUND.

"Last summer Tom and I saw a man chopping wood," said Amy. "He was quite a distance from us; we counted three from the time we saw the ax strike the log until we heard the sound."

"When the whistle blew at noon yesterday," added Willie, "I saw the steam a few seconds before I heard the sound."

You have certainly made good use of your eyes and of your minds too. If you know how fast you count, you can in that way get an idea of how fast sound travels. It has been found that sound travels about eleven hundred feet a second.

In the last thunderstorm I counted ten between a flash of lightning and the thunder. If I counted two a second, how far away was the lightning?

"Once when we were out swimming," said Willie, "my friend slapped the water with his hand. I was a little distance away from him, and put one ear down in the water and one above water. When he struck the water I heard two sounds, one after the other; the ear under water heard the sound first, and it seemed to be louder than the sound heard by the other ear."

Here is a pole twelve feet long. I will lay my watch on this end of it, and you put your ear to the other end. Can you hear the watch tick, Amy?

"Oh, yes, very well; but I can't hear it if I don't put my ear to the pole."

What does all this teach you, Tom?

"It teaches me that sound travels better in wood than in air. It travels well in water and iron, too. Not long ago I put my ear to the rails, and heard the sound of the train when it was so far off that I could not hear it in the air."

QUALITY AND PITCH.

How do we know a voice?

Tom and Willie, you may go out into the other room and talk with each other.

Amy, can you tell which is Tom's voice?

"Oh, yes, very well."

How do you know it from Willie's voice?

"I think it is because Tom does not talk so loud as Willie."

Yes, that is part of it; but is there not another difference? Listen.

"I think Willie's voice is lower; Tom talks in a high key."

Yes, that is true. Can you hear other differences?

Now come in, boys. Amy can tell which of you is talking if she cannot see you, she says. Tom's voice is in a higher key, but not so loud as Willie's. Can you think of any other differences?

"I am sure there are some, but I don't know what they are," said Willie. "Tom and I each have a violin. We may tune the violins just alike, and yet I can tell which is mine. I know it by the kind of tone."

That is right, Willie. This difference in kind of tone we call "timbre," or quality of tone. In violins it is the kind of wood and the form of the instrument that make the difference in the sound. It is claimed that the older a good violin is, the better is the quality of its tone.

VIBRATION OF STRINGS.

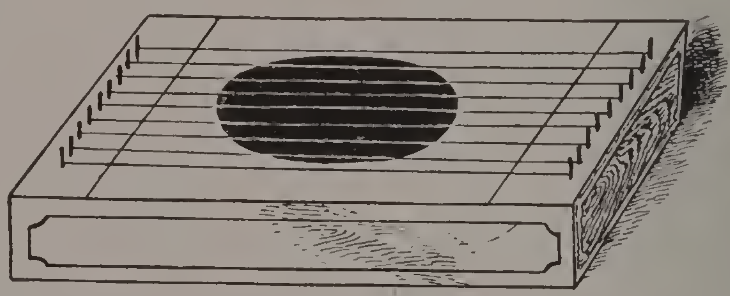
"I HAVE an Æolian harp at home. I made it myself. When the wind blows, I open the window and set the harp under it. The wind plays on it beautifully. The music is soft and sweet."

How did you make your harp, Willie?

"I took a board two and a half feet long and six inches wide. Near one end I put ten small nails, and at the other end ten screw eyes for the strings. I made the strings of good silk thread, well waxed. The first string was a single strand, the second double, the third triple, and so on; each had one more strand than the one before it; the last one was made of ten strands."

Why do you have strings of different weights?

"So that there will be different tones. The thick strings produce lower tones. I can also make a higher tone by pulling the string tighter. The more the string is stretched, the higher the tone will be. I learned that from my violin. I put two narrow pieces of wood under the strings crosswise and

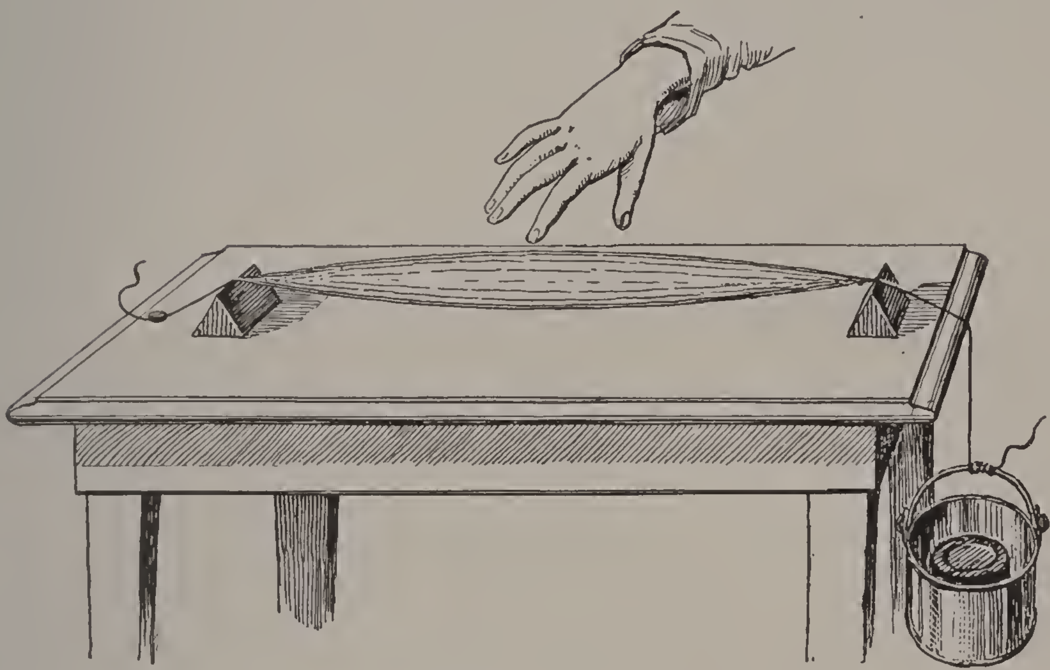


Æolian harp.

pushed them near the ends of the board, so as to stretch the strings. I believe they call these pieces bridges."

That is well described, Willie.

Now let me drive a tack into the table, and fasten one end of this thin wire to the tack, and the other to a tin pail into which I'll put a half-pound weight, so as to stretch the wire across the table. In order to



Wire vibrating.

raise the wire from the table, I shall put bridges near each end. Now pull or pluck the wire; notice what happens.

"I see the wire move up and down; it moves farthest in the middle."

I will now double the weight in the pail and pluck the wire.

"The tone is higher," piped out Tom.

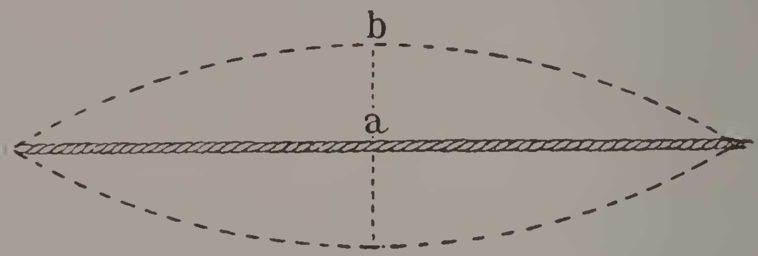
"Yes, and the wire moves quicker."

Say "vibrates" instead of "moves," Amy. Now

I'll put a third bridge under the middle and pluck half the wire.

"Oh, see how rapidly the wire vibrates!" shouted Tom and Amy together.

"The tighter the wire," put in Willie, "the faster it vibrates, and the shorter the wire the faster it vibrates. The faster the wire vibrates, the higher the



Vibrating cord. *a*, cord at rest; *b*, line taken by cord in vibrating; *a* to *b*, amplitude of vibration.

tone, and the harder you pluck the wire, the louder the tone."

You can learn many interesting things from the strings of your harp. Make what is called a "rider" by folding a piece of paper into a strip a quarter of an inch wide and then creasing it in the shape of the letter V. The rider may be hung on any of the strings and at different places. The effect will surprise you.

"Our piano," remarked Amy, "has long thick wires for the low keys, and short thin wires for the high keys. Now I understand why this is so."

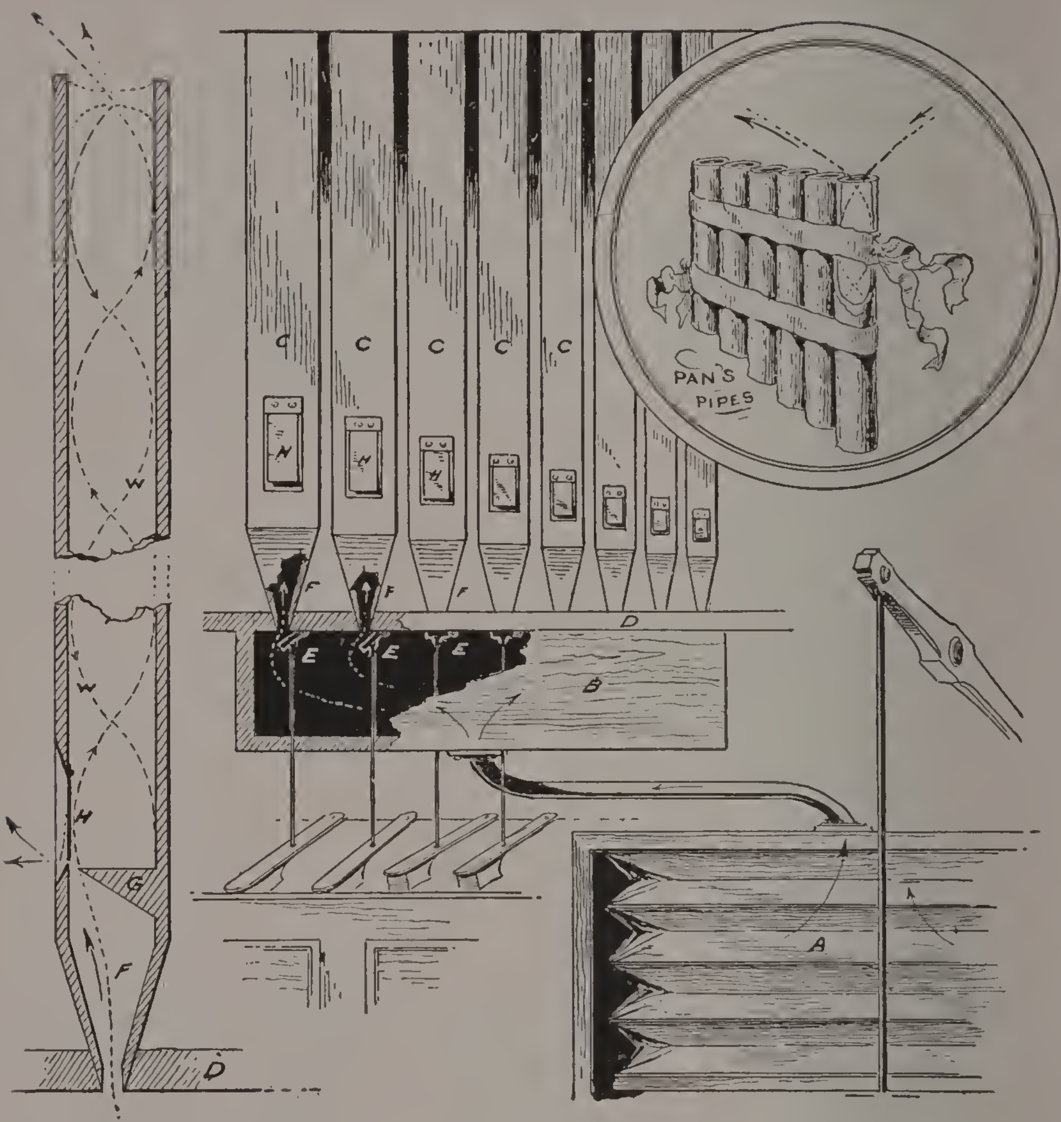
To this Willie added: "I pulled some of the reeds out of our organ and noticed that those for the low keys were about two inches long, a quarter in width, and as thick as a knife blade, while the one for the highest key was only half an inch long, a sixteenth in width, and as thin as paper."

"Last spring," said Tom, "I made a whistle from a willow twig. I noticed when I pushed the plug in it made the tone higher, and when I pulled it out it was lower."

Yes, the shorter the column of vibrating air the higher the pitch; that is, if the diameter of the column remains the same. But, as in the case of strings, the greater the diameter, the lower the pitch. You can find this out by whistling in different keys. When does the wind whistle round the corner of the house in a high key? Is it when it blows hard?

Organ pipes are constructed on the same principle as the willow whistle. The air from the bellows enters the "mouth-hole" and makes the column of air in the pipe vibrate. The longer or the larger the pipe, the less the number of vibrations per second, and hence the lower the tone. Organ pipes are often cylindrical.

Isn't it wonderful! Think of the many kinds of instruments, and no two produce tones exactly alike! We can listen to a band of thirty or more and distinguish the tones of all the different instruments.



A, bellows for air-force; *B*, receiver or reservoir, from which air is supplied to pipes *C C C C C* through the sounding-board *D*, by valves *E E E* into mouthpieces *F F F*, passing bridge *G* that extends nearly across pipe, leaving narrow opening through which the current of air rushes, pressing against elastic metal tongue *H*, causing it to vibrate rapidly, and thus producing the sound-waves that pass out at the top of the pipe in regular modulations. Or, if the pipe is closed at top, these waves are reflected back in the same geometric lines to escape at the opening in which the metal tongue vibrates.

There are the notes of so many birds, animals, and the hundreds of insects, and the quality, force, and pitch of all are produced by changes in the vibrations of the air.

"That's more than I can imagine," said Tom.

There is something that is still more wonderful; and that is the ear, which is so made that it can distinguish all the delicate variations.

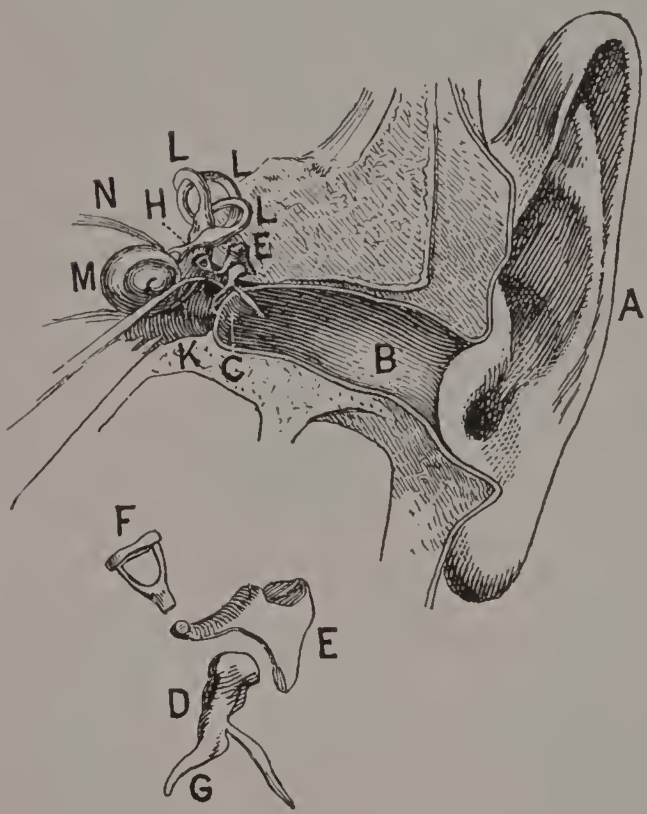
"Oh, tell us about the ear," exclaimed all three.

THE EAR.

I WILL begin by telling you that you probably never saw an ear. You have seen the external ear; but that is only the entry—we might say, the part which gathers up the vibrations. Some animals do not have this part of the ear.

I will show you a picture that will help you to get the correct idea of the true ear. It would be better if you could see an ear. When I studied the ear, I obtained a hog's head at the market to dissect both the ear and the eye. I took a sharp chisel, and with it carefully cut away the bone in which the ear is situated, bit by bit. It was an easy task, and I saw every part of the ear.

The external ear is connected with the true ear by a passage into the bone of the head about an inch long. Its inner end is closed by a thin elastic skin or membrane, which is stretched across it like the membrane of a drum. There is no doorway through this. Inside of this membrane, in what is called the middle ear, are three small bones, named, from their shape, hammer, anvil, and stirrup. The hammer handle lies against the drum of the ear, and the head is attached to the anvil bone. The stirrup bone is very small and is fastened to the anvil so that the stirrup end is in front of a small oval opening or window which leads into the inner ear. There is also a tiny tube from the middle ear to the throat.



The human ear. *A*, external ear; *B*, passage into the inner ear; *C*, ear drum; *D*, hammer; *E*, anvil; *F*, stirrup; *G*, handle of hammer; *H*, small oval opening into the inner ear; *K*, vestibule; *L L L*, bony passages; *M*, cochlea; *N*, nerve to brain.

The third part or inner ear has a small chamber about the size of a pea, called the vestibule. From this are round openings into three bony canals in the shape of a half circle. In front of these is another opening into a snail-shaped, bony spiral, the cochlea. On the inner wall of the cochlea is spread out the nerve of hearing. The internal parts of the ear contain a watery liquid.

The sound vibrations enter the external ear, pass through the drum and the three small bones, one after the other, into the vestibule and through the water, and then they are taken up in the cochlea by the nerves of hearing, which report them to the brain. Thus sound passes through gas, solid and liquid, the three forms of matter, before it reaches the nerves of hearing.

"It seems to me," thoughtfully remarked Willie, "the brain has the most wonderful part to do, as the sound waves are still vibrations when they reach the nerves."

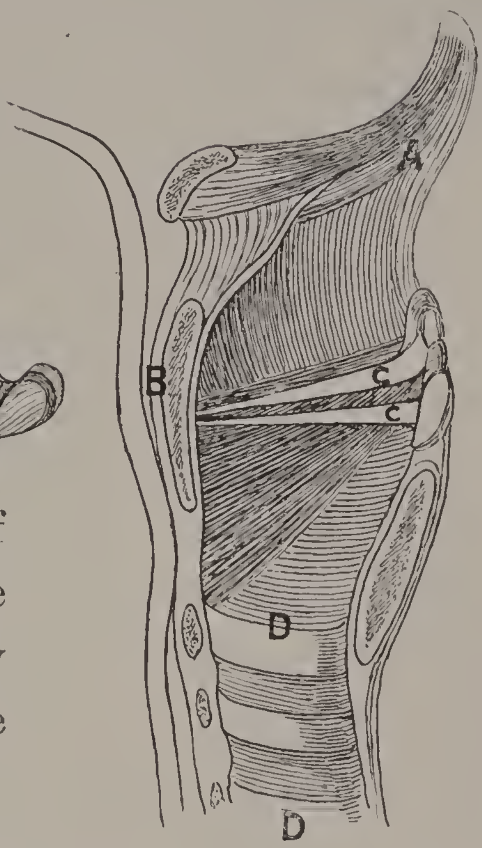
True, one wonder follows another, and each leads to another still more surprising. But we must leave the study of the ear here. I wish, however, to say that the ear should be tenderly treated. A blow on the ear has often produced serious effects. We should never clean the ear with a pin or with any other hard point without first carefully winding the point with cotton. The wax must not be left in until it has been hardened by dust, as it will affect the hearing. Smoke and cold air breathed in through the mouth irritate the tube leading to the middle ear and thus often injure the hearing.

I may also add that the ear is one of the avenues by which the mind gets knowledge. It is just as important to have a large number of sounds stored in the memory as it is for the merchant to have a full line of goods on his shelves in order to serve his customers. There are the many voices of Nature and the variations of musical tones, to say nothing of human voices, no two of which are exactly alike. How many human voices are you able to distinguish? Make a test among your friends.

"What is it that makes the voice?" inquired Tom.

The voice may be called a wind instrument, because it is air that produces it. It works in the same manner as the organ, the harmonica, or the Jew's-harp.

The upper part of the windpipe forms a cylindrical box which you can feel with the fingers. It is often called Adam's apple, but its proper name is larynx. Across the top of it are stretched two elastic membranes, a half circle in shape, so that at one side their edges touch, and at the other they are slightly separated, thus forming a narrow V-shaped slit. When we wish to speak, we tighten these vocal cords, as they are improperly called—vocal membranes would be a better name—and force air through them to make them vibrate, which gives the tone. By putting the fingers on the larynx you can feel the vibrations and the tension of the tube when changing from a low to a high tone. You can find out for yourself what effect the shape of the mouth has on the tone by changing the position of the lips, tongue, and lower jaw.



Organs of speech. *A*, epiglottis; *B*, larynx; *C*, elastic membranes; *D*, windpipe; *C C*, separate figure of elastic membrane.

Would there be any sound, boys, if there were no ears?

"There would be no one to hear it," Amy replied.

"Niagara Falls," observed Willie, "roared just as loud before there were any ears to hear them as they do now."

Before answering the question I have put to you, we must decide on the definition of sound. Is sound a certain vibration of the air? If so, there has been sound as long as there have been sound-producing bodies. But if we say sound is the impression of the air vibrations on the brain, after they have been passed through the ear, then the vibrations are only a condition of sound.

"Then there would be no sound except in brains," interjected Willie.

You may take your choice of definitions and answer the question accordingly. I want to give you a few other questions to think about. Of what use is the outside part of the ear? Why do some animals, like the mule, have large ears, and others, like the bird, small ones? How can we tell from what direction the sound comes? Can a grown person tell better than a child? Why? Do sound vibrations move in straight lines? When the bell rings, stand so that the house is between you and the bell. How is an echo produced?

HEAT.

You say you made some experiments yesterday, boys. Will you tell us about them?

"Tom took a red-hot coal out of the stove," Amy replied. "I put my hands all around it and felt the heat. I felt it below the coal, too."

To this Tom added: "We found that the farther from the coal we held our hands, the less heat we felt."

"That's because the farther away, the more space the heat must warm," put in Willie. "Yes," Tom continued, "and when I put a piece of cardboard between the coal and my face, I did not feel the heat. That shows that the heat must travel in straight lines or it would go around the board."

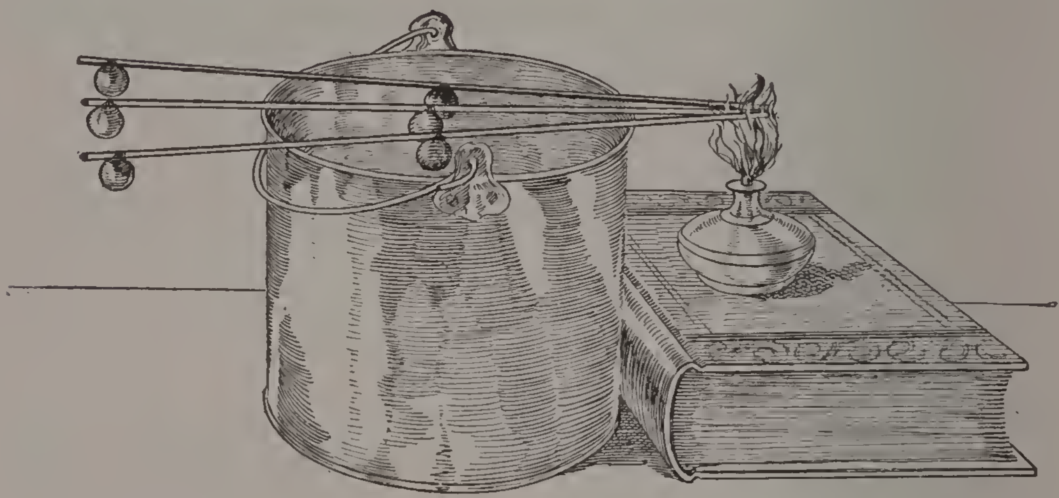
Good; you did well, Tom and Amy. I can see by Willie's face that he, too, has something to tell us.

CONDUCTION.

"I HAVE often noticed that our iron griddle-holder gets much hotter than the one with the wooden handle. So I got a stick just the size of our iron poker and put one end of the poker and of the stick in the fire. In ten minutes the iron poker was so hot at the other end that I could hardly touch it, but I could take hold of the wooden one a foot from the fire. I concluded that heat does not pass through wood as well as it does through iron.

"Then I went to the tinsmith and got three wires, each twelve inches long—one iron, another brass, and the third copper. They were all of the same thickness. I laid them on top of a tin pail so that one end of each was in the flame of a lamp and the other ends were separated. The copper heated through first, and then the brass.

"With a bit of cobbler's wax I stuck two marbles on each wire, one six inches from the flame, the other twelve inches. The marbles which were nearer to the flame fell off; the one on the copper in one



Experiment in conduction.

minute, that on the brass in two minutes, and the one on the iron wire in a little over six minutes. The marbles twelve inches from the flame fell off—from the copper in something over two minutes; from the brass in a little over four minutes; and from the iron in twelve minutes. So I concluded that heat moves twice as fast in brass as it does in iron, and six times as fast in copper as in iron. I think some heat was lost from the iron, especially by the time it reached the second ball."

You are a genius, Willie. Your conclusions are almost the same as those of the great scientists.

When heat passes through the air from a hot object, we say it radiates from the object, and when it passes through a solid from particle to particle we say it is conducted by the copper, brass, or whatever the solid is. The things that conduct the heat are conductors. A thing which conducts heat rapidly we call a good conductor; one which conducts heat slowly, a poor conductor.

"Is it right to say that cloth is a conductor?" inquired Tom.

Yes, and different kinds of cloth have different rates of conduction. I will tell you about some interesting experiments that I have made. I cut ice into inch-cubes and then tied them into patches of different kinds of cloth. I did this in the cold air, in order that they should not begin to melt until all were ready. Then I hung them in a warm room so that they were separated from each other and from the wall. I noticed their rate of melting. I will not give you much of the results, for it will be more valuable to you to make the experiment yourselves. Only this, the ice in the linen melted first, in the cotton next, and in the woolen last; and dark colors are better conductors than light ones.

I also laid pieces of different kinds of cloth on the snow in the sunshine and observed the effect of the sun on the snow under each piece. The results were the same as those in the previous experiment.

These tests teach us that we should wear light clothes in summer, and linen or cotton rather than woolen. In regions where cold winds are liable to come up quickly, it is well to wear, even in the warmest weather, a thin woolen garment next to the skin, to prevent chilling.

CONVECTION.

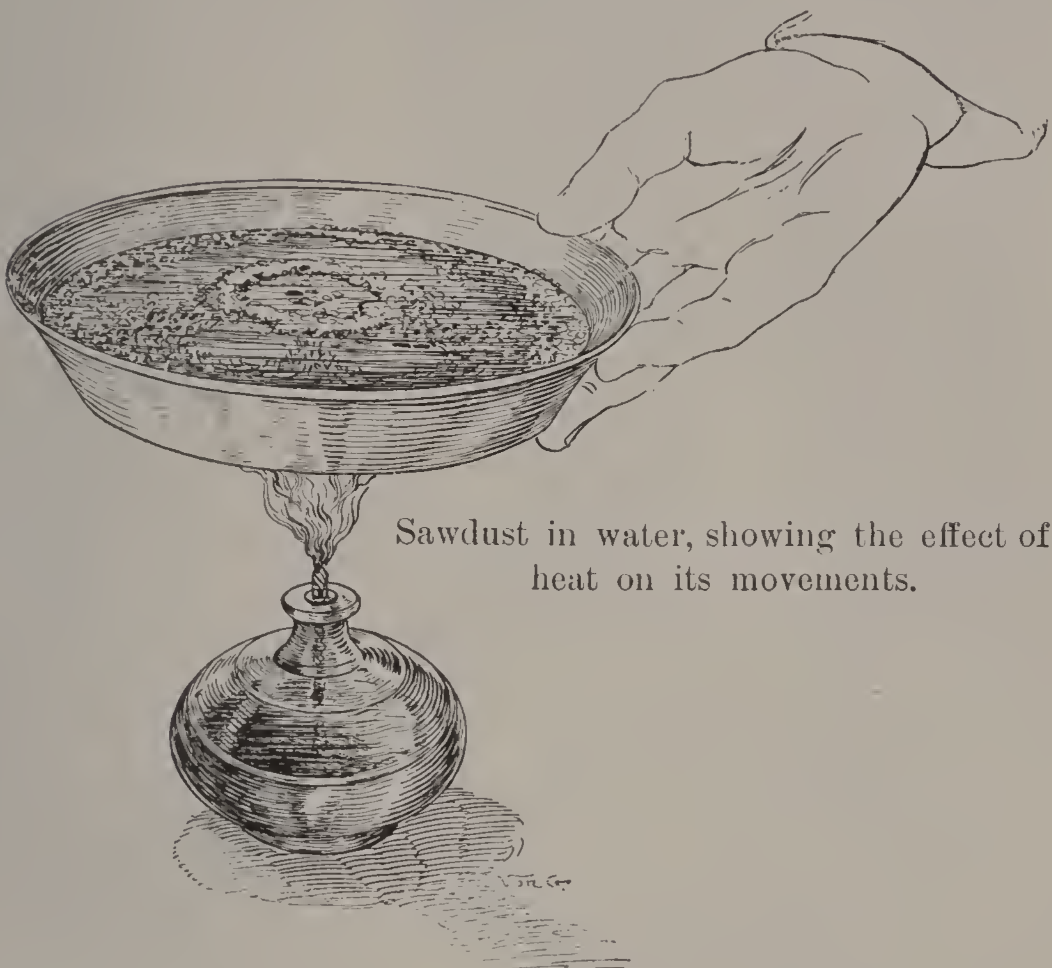
I WILL now show you something else. I'll set this panful of water over the flame of the lamp and throw a little fine sawdust in the water. Now, tell what you see.

The boys were polite, and as Amy was a girl and the youngest, too, they looked at her to see if she did not want the first chance to speak. You can see that she had made good use of her eyes from the following answer:

"I see the sawdust in the water just over the flame move upward a little, then toward the sides of the pan and down again. Now the sawdust comes up to the top before it goes down again. I think it's getting hotter."

She added: "I think the sawdust shows which way the water moves. When the water over the flame of the lamp gets warm, it begins to rise and move in almost a circle, but I cannot tell why it does so."

"I think I can tell why," said Willie, timidly. "When water becomes warm it gets lighter, and then the cold water pushes it up, as it does an orange when you push it down in water. We learned that



Sawdust in water, showing the effect of heat on its movements.

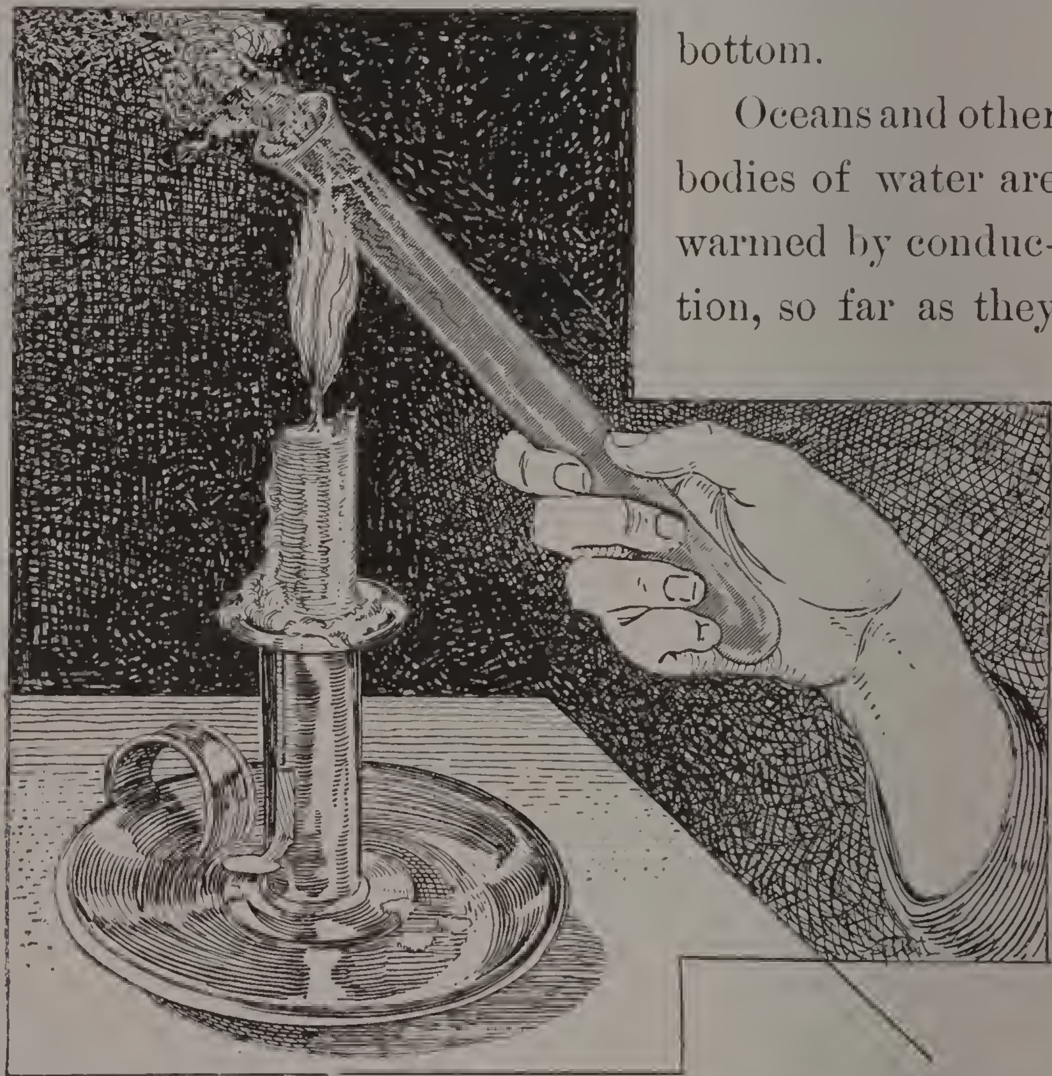
last year. The cold water nearest the flame pushes the warm up, itself becomes warm, and is in turn crowded up. In this way the water in the pan begins to move in a circuit."

Your conclusion is correct, Willie. This way of transferring heat is called convection.

Gases and liquids are best heated by convection.

Liquids can be heated by conduction by applying heat at the top, but it is a slow process. The illustration of the test tube shows the water boiling at the top, but still cold at the bottom.

Oceans and other bodies of water are warmed by conduction, so far as they



Test tube containing water boiling at the top but cold at the bottom.

are warmed at all. Of course the water in the torrid zone is warmer than that in the frigid zone, and is therefore forced from its place by the colder water, thus producing currents. These currents aid in warming the cold regions, but the ocean, even in the torrid zone, is not warm far below the surface. The oceans at a depth of about three miles are at the freezing temperature.

This room is heated by a furnace. You see if I hold this paper over the register, it flutters as if the wind blew up through the register. When I hold it near the floor you may see that a current of air moves toward the register. This proves that the air circulates in the room, and thus warms all parts nearly alike.

Tom, you say your room is warmed by a stove. Hold a strip of paper in different parts of the room and see if you can find currents. Hang a thermometer near the ceiling and one near the floor, and tell us what they teach you; also, hold a strip of paper near the top and bottom of an open doorway between a warm and a cold room. Perhaps you can discover some currents that will interest you.

The fact that heated air and water are lighter than cold and therefore rise, accounts for winds and ocean currents. As soon as the air is unequally heated in different regions, a current sets in from the colder place toward the warmer, thus creating a wind. Mountains have their influence in changing the direction of the wind, and so does the rotation of the earth on its axis.

The atmosphere receives little heat from the rays of the sun as they pass through it to the earth. It is heated chiefly by reflection and radiation. Those who have ascended in balloons to a distance of from three to four miles above the surface have found the air so cold that they could scarcely keep from freezing even in heavy clothing.

When the rays of the sun strike the earth, part of the heat produced is reflected or thrown back, but by far the greater part warms the land and water, and these in turn radiate the heat to warm the atmosphere.

EXPANSION.

"I TRIED something else," said Willie. "I went to the tinsmith and had him punch a hole, just large enough to fit an iron rod that I had, in a piece of tin. Then I heated the rod and tried to put it in the hole, but it was too large now; heat made it swell up, if that is the right word."

We say heat "expanded" the iron.

"Then I heated the rod and measured its exact length by setting up two flatirons, one against each end. After cooling the rod, I laid it again between the irons, and found that it was shorter. I concluded that heat expands iron both in thickness and length."

"I saw a blacksmith heat a wagon tire the other day," said Tom, "and then put it on the wheel. It went on easily, but after he had cooled it with water it was so tight that you could not knock it off with a hammer. He said if he should make the tire red-hot and fit it closely, he could make it so tight that it would bend the spokes, if not break them."


The expansion of an iron rod by heat.

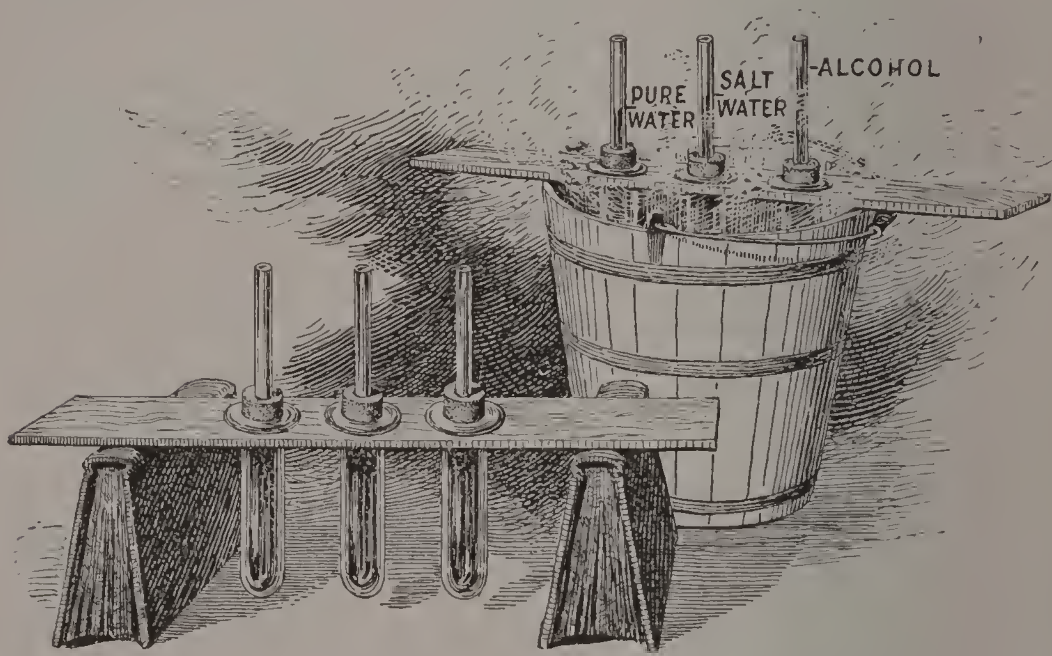
"When I crossed the railroad tracks this morning, I noticed the rails did not come together, and last summer they were against each other so closely that I couldn't put a pin between them," added Tom.

The expansion of iron and steel must be taken into account in building bridges; for if all the parts were bolted together tightly in cold weather, the heat of summer would expand the metal so as to break the fastenings.

You can easily try other metals as Willie did the iron, and you will doubtless find that the best conductors expand the least. That will give us something to talk about next year.

I will now show you an interesting experiment.

Each of these test tubes is fitted with a rubber cork through which passes a small glass tube. They are supported in the holes of this little board. In one is fresh water, in another alcohol, and in the third strong salt water. I have added a few drops of red ink to each of the liquids so that they may be more easily seen through the glass.



Expansion of liquids.

The tubes are filled; the liquids stand just at the upper edge of the cork. Now watch the effect as I set them down into this pail of hot water.

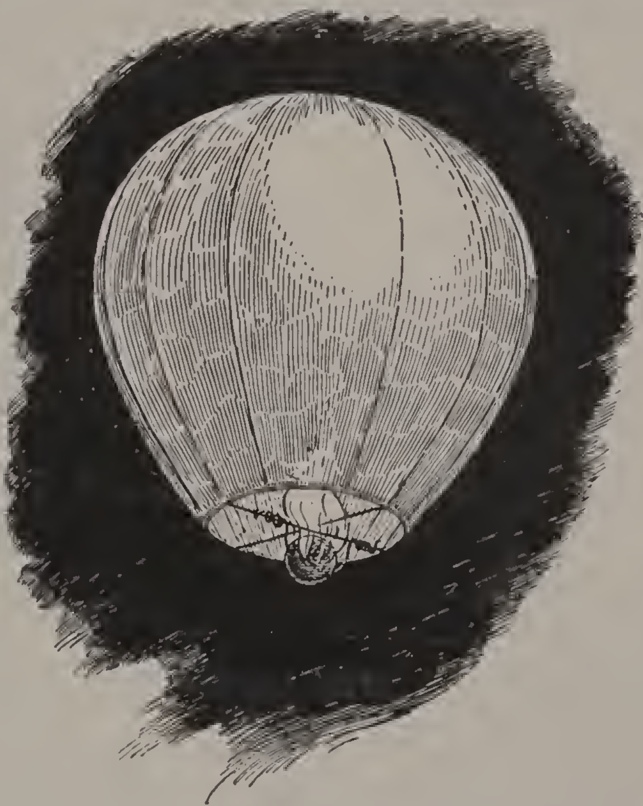
Amy, what have you noticed?

"I saw the liquids rise in the tubes; the alcohol rose first and highest, next the salt water, and the clear water rose last. That looks as though the water increased when heated."

"That is the way a thermometer works," interrupted the boys.

You observed well, Amy; but there is no more water now by weight than there was when it was cold. As soon as it cools, it will fall to the top of the cork again. A pound of cold liquid will weigh just a pound when heated.

I think this is what happens when a liquid is heated: the heat gets in among the tiny particles of the liquid and pushes them farther apart; this makes them take up more space.



A fire-balloon made of tissue paper.

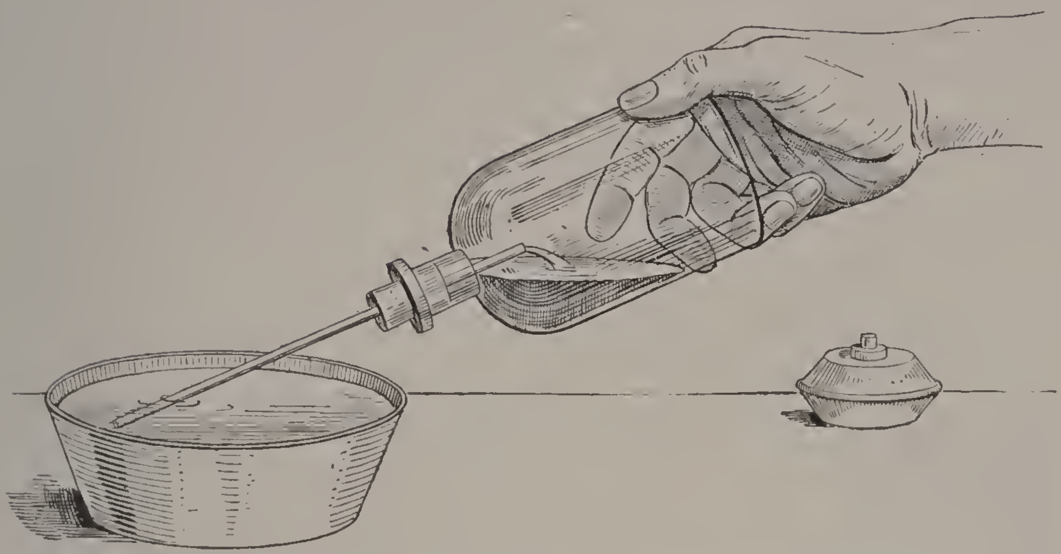
"That is why warm water is lighter than the same amount of cold water," interrupted Willie.

Air and other gases also expand in bulk when heated. You can see, by filling a little rubber balloon in the cold air, measuring it around with a tape or string, and then taking the balloon into a warm room and measuring it again, that gases expand when heated.

"We made a balloon of thin tissue paper last Fourth of July," said Tom. "It was the shape of an egg with the small end cut off a little. We put a light wire in the opening and fastened a little ball of absorbing cotton to it so that it did not touch the paper. Then we poured alcohol on the cotton and touched a match to it. The flame heated the air in the balloon, and when it was light enough it sailed away. It went up very high, and as long as the cotton burned the balloon kept afloat. It was lots of fun for us all."

Heat expelling air from a bottle.

Here is a bottle which has an air-tight cork into which a long tube is fastened. I will put the end of the tube under water and hold the flame of the lamp under the bottle. As the air in the bottle becomes warm, bubbles rise from the water. Now as it cools, see the water rush up the tube into the bottle. It is half full. When the air was heated its pressure was

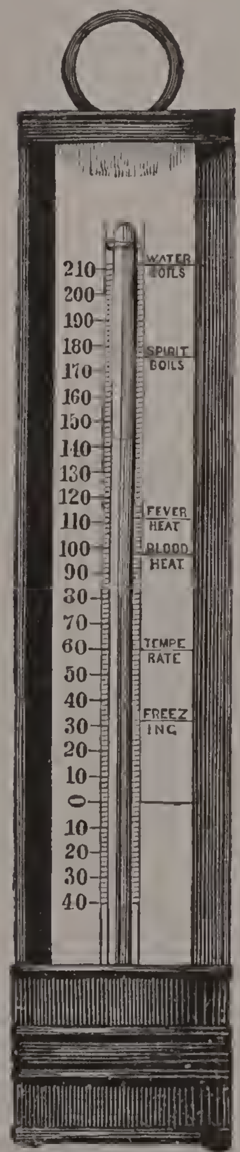


Air forcing water into partial vacuum.

greater than that of the atmosphere outside and a part of it was forced out. As soon as it cooled the greater pressure was outside and forced the water into the bottle. From the amount of water in the bottle you can see that the air in it had been expanded to twice its original size, and the heat forced half of it out.

Mercury, melted lead—in fact, solids, gases, and liquids—contract as they cool, but water and a few other things are exceptions to this rule. You have often seen ice floating on water. It would not do that unless it were lighter than water. The following experiment was interesting and taught me something :

I inserted a rubber cork fitted with a small tube, in a test tube full of water until the water rose two inches in the small tube. Then I suspended it in a pail of water with a correct thermometer beside it, and set it out on the window sill. As the water cooled it sank in the tube, but only until the thermometer fell to 39° F. Then as the water got still colder it rose rapidly in the tube and ran out at the top just as it began to freeze. This showed that water was most dense at the temperature of 39° F. and expanded considerably before it became a solid.

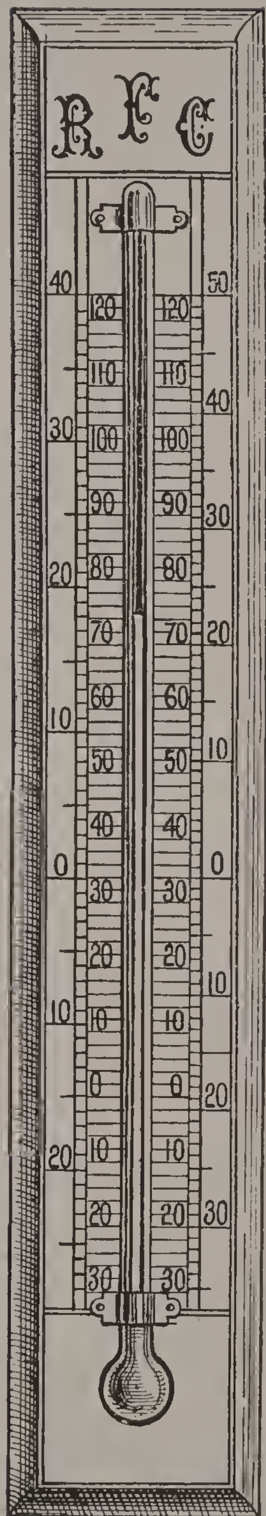


Thermometer.

This is a wonderful and a wise exception. If it were not for this the ice would sink as fast as it formed; our streams in the cold climate would freeze solid in winter, and it would take all summer to thaw them out.

THERMOMETER.

I must tell you how I made a thermometer (*thermo*, heat, and *meter*, measurer). I bought a thermometer tube with mercury in it. Then I fastened a strip of card to the tube so that marks could be made on it. Next I put the bulb in a cup of water which I set out on the window sill on a cold day. The cold contracted the mercury so that it fell in the tube. Just as the ice was beginning to form on the water I made a mark on the card at the point where the mercury stood. This was the freezing point or temperature. Then I placed the bulb in boiling water and noticed to what point the mercury rose and made a mark. This was the boiling point. I thought it would be a good idea to call the freezing point zero and the boiling point a hundred. Fahrenheit, whose thermometer we generally use, called these points 32 and 212. The distance on the tube between the two points is the same. I divided the space into one hundred parts, and Fahrenheit divided his into one hundred and eighty parts. Five of my divi-



Compound thermometer (—30° to 122 F.°). R., Réaumur; F., Fahrenheit; C., centigrade.

sions were equal to nine of his. My thermometer is called a centigrade thermometer (*centum*, hundred, and *grade*, step) because there are one hundred steps or marks from the freezing to the boiling point. This kind is used mostly by scientists. There is a third kind called Réaumur. By looking at the picture you can see how the different divisions or scales of these three thermometers compare with each other. Which kind do you think the most convenient?

HEAT REQUIRED TO CHANGE FORM.

I HAVE often observed the fact that when snow or ice melts, the water remains ice cold until all the ice has disappeared. I put a pound of water at a temperature of 176° and a pound of chopped ice having a temperature of 32° F. in a two-quart fruit jar and gently stirred the contents until the ice was melted. The water in the jar was now at a temperature of 32° F. It had lost 144° and the water from the ice had gained nothing in temperature; it was still at the freezing point. What became of that heat? It certainly was not lost.

I think it took that much heat to break up the ice, to change its form from a solid to a liquid. Everything, however cold, has some heat in itself. We may not be able to measure it with a thermometer, but it is there, invisible to us. The water that came from the pound of ice has 144° more of heat in it now than it had when it was in the form of ice.

Then I tried the same experiment in a cool room, but this time I used water at a temperature of 180° F. or 148° above the freezing point. After the ice had melted the temperature of the water rose to 34°, that is 2° above freezing. Thus I concluded that to change the form of a pound of ice to a liquid requires 144° F. and no more, and the other 4° were used in raising the two pounds of water together two degrees.

There is another thing you may have seen, and that is that plants are often kept from freezing in a cold room or in the cellar by setting a tub of water near them. In the morning I have seen the water frozen over with a sheet of ice, and the tender plants uninjured. Doubtless, water gives out as much heat in freezing—that is, in changing from a liquid to a solid—as the ice takes in in melting.

SOURCES OF HEAT.

What sources of heat can you think of?

"We get heat from the sun, from wood, and from coal," responded Amy.

Tom added, "The auger gets hot in boring holes; the ax too, if you sharpen it on the grindstone without water, and if we rub anything it gets hot. I read that they used to make fire by rubbing two sticks together."

"Electricity makes heat, too, for they warm cars with it. I poured some acid in water, and it made so much heat that I could not hold the bottle," said Willie.

Your answers are good. The sun is the great source of heat. Later you will learn that even the heat in fuel is sunlight stored away ages ago for our use. The third source of heat is friction; that is, heat produced by rubbing or pounding. The case of acid and water may also be classed as friction of their particles.

WHAT IS HEAT?

"You have not told us anything about what heat is," interrupted Tom.

That is no easy question. But I will give you some idea about it. You remember we concluded that sound is wave motion of the air.

"Isn't heat also waves of the air, but of a different kind?" inquired Willie.

Not exactly. I once saw an experiment in which a thermometer was suspended by a silk thread in a bell jar and the air exhausted from the jar.

When hot coals were brought near the jar, the thermometer at once rose, showing that heat passes through a vacuum, and that air is not necessary for the radiation of heat.

To explain heat, light, and other forces, scientists suppose that something much thinner than air fills all space, a substance so thin that it goes through all objects, that is, permeates all bodies, and is very elastic but without weight. This imaginary fluid they call ether. Heat is supposed to be waves or vibrations of this ether.

When a coal, for instance, gets warm its molecules begin to vibrate, and the warmer it gets, the more rapid the vibrations. These vibrations set the ether in the coal and all around it in motion. The waves move outward in all directions like sound waves from a bell.

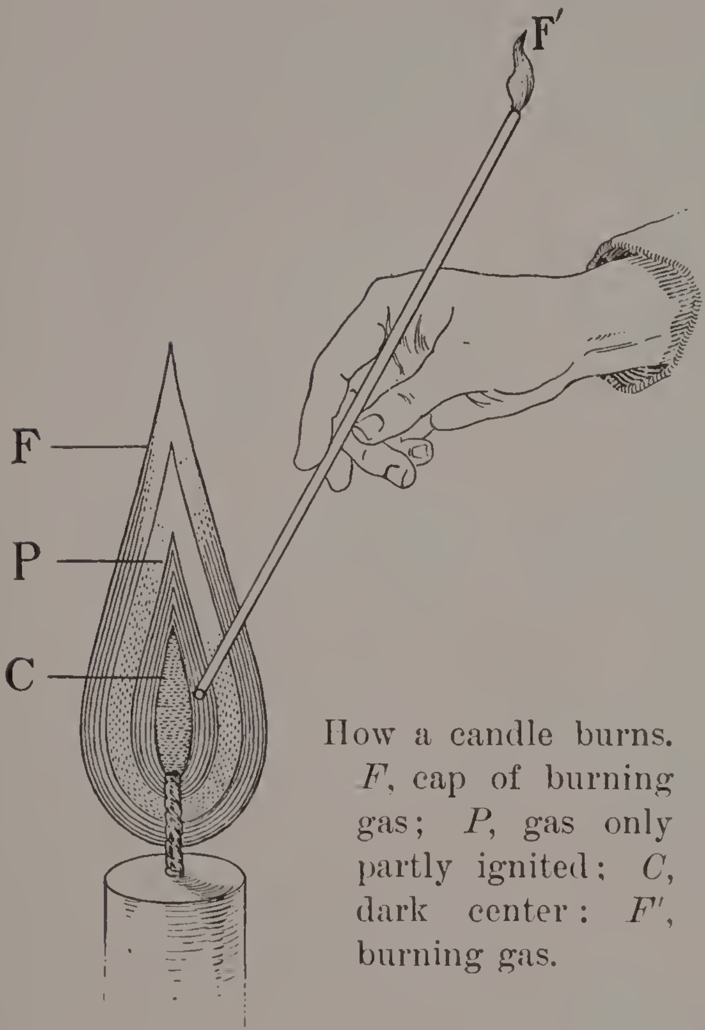
LIGHT.

"Oh, see here," exclaimed Amy. "I held this card across the middle of the flame of the candle and it made a black ring on it. The card is as white inside of the ring as it is outside. That looks as though the flame did not burn in the center."

I will light the tallow candle, and ask you to observe what the flame does.

"The heat of the flame," said Willie, "melts the tallow and then burns it."

There is another step which you can not see. Here is a glass tube drawn to a point. I will hold it with the large end in the center of the flame and put a lighted match to the pointed end.



How a candle burns. *F*, cap of burning gas; *P*, gas only partly ignited; *C*, dark center: *F′*, burning gas.

"It burns like gas," spoke up Tom. "I believe it is gas."

"I know now," continued Willie. "The other step is changing the liquid to gas. Now let me say it all. The heat changes the tallow to liquid, then the liquid to gas, and then the gas to flame."

You have the order correct. You see the dark center in the flame. That, as you see, is unburned gas. Around and over the dark center is a cap of burning gas. This cap is lined with a layer of gas only partly ignited; that is, it is just beginning to burn.

LIGHT MOVES IN STRAIGHT LINES.

"I HAVE just found out that light moves in straight lines," said Willie.

What is your proof?

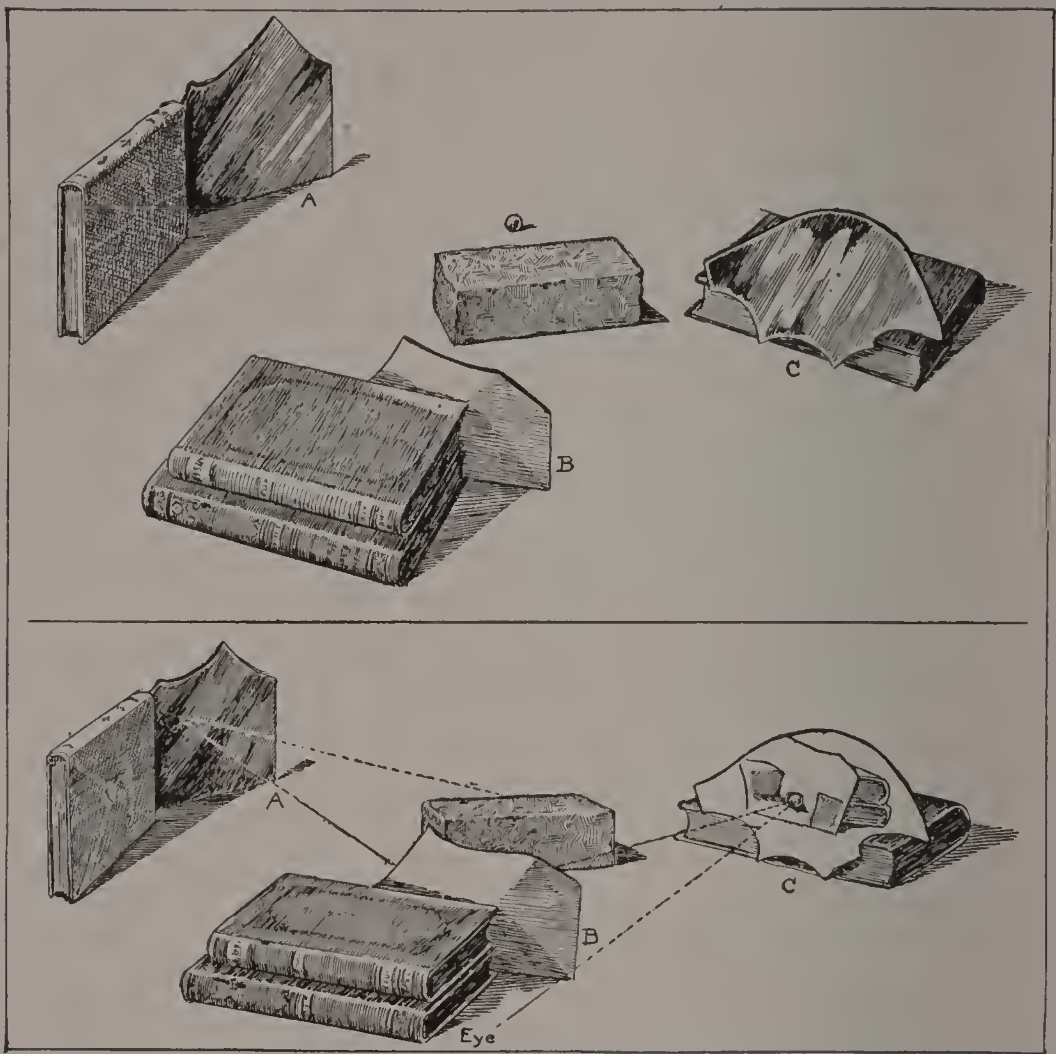
"I have three cards here with a small hole exactly in the center of each. I set them one behind each other and looked through the holes at the flame. If any one of the cards is the least bit too high or to one side I can not see the flame. The holes must be exactly in line or the light will not come through them to my eye."

"Oh, I always knew that. You can't look around the corner of the house unless you put your head around it," put in Amy, laughing.

LIGHT IS REFLECTED.

"I CAN show you how you can see through this brick," continued Willie.

So he laid the brick on the table with a marble behind it, arranged books and pieces of an old mirror at the corners, *A*, *B*, and *C*, as you see in the picture. Then he went on to say: "The light comes from the marble and strikes the glass at *A*, and this reflects it so that it strikes the glass at *B*, which sends it to *C*, and from *C* it comes to my eye. Look for

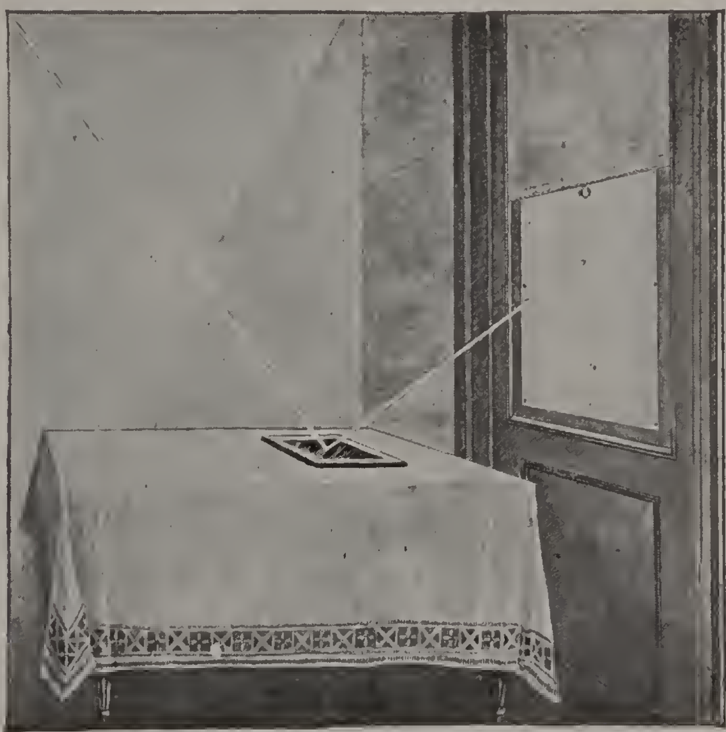


How to see around a brick.

yourself, Amy, and be convinced that you can see round the corner of a brick, if not round that of a house."

Are you certain that the light comes from the marble to your eye? Does not the light strike your eye first, and then pass from your eye to the marble? Does the eye see objects where they really are? Have you ever seen the image of a boat or other object in the air upside down?

Through the paper shade which I have placed before the window I made a hole half the size of a lead pencil. Now I'll lay the mirror on the table so the sunbeam coming through the hole in the shade will fall on it. I'll stir up some dust so you can see the beam better. Notice the direction of the reflected ray. Now, if one end of the mirror is raised a little, the direction of the reflected ray will also be changed.

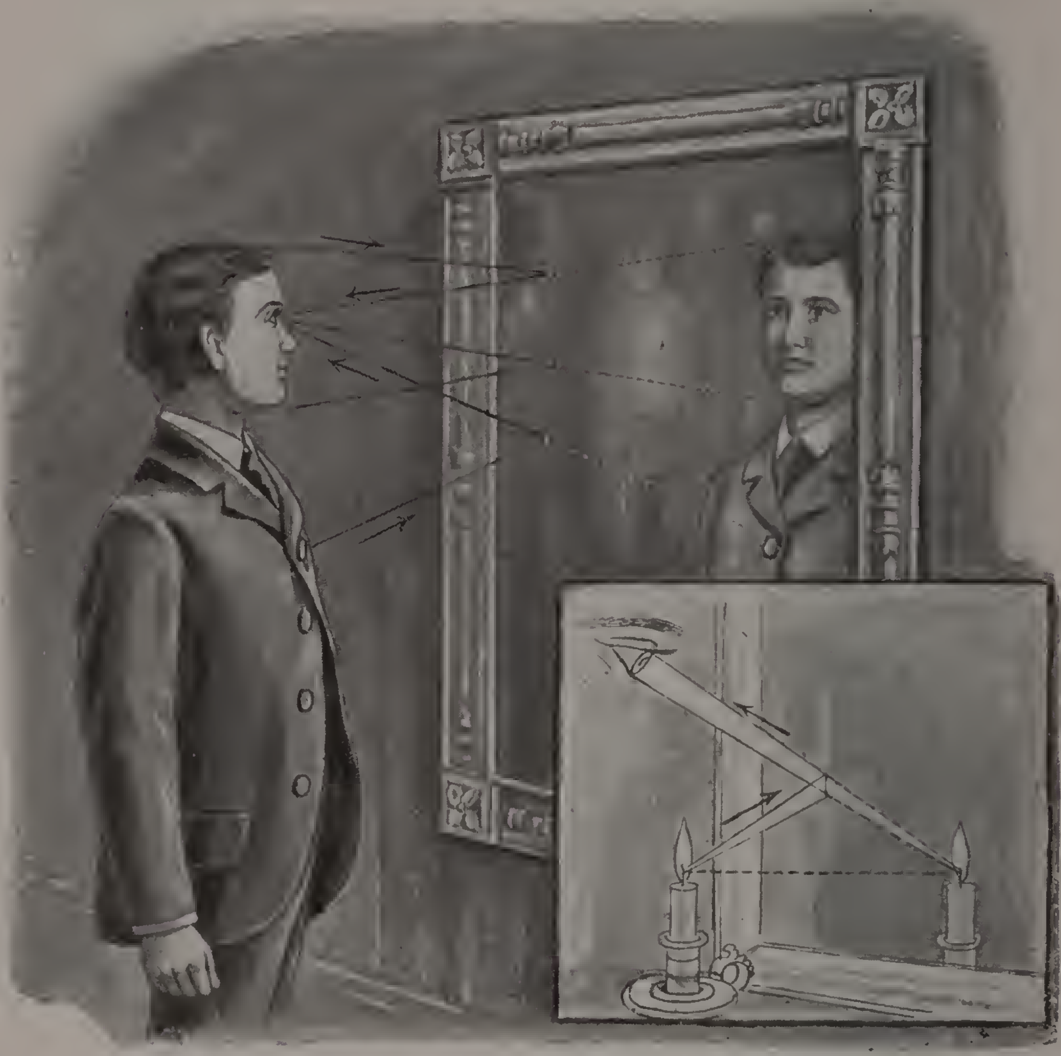


Ray of light is reflected at right angles.

Look at the objects in the room. You can see them by the reflected light. If there is little light, the objects will reflect little and will be indistinct.

"Do we not see all objects, even those outdoors, by reflected light?" asked Willie.

Yes, with a few exceptions. These are the sun, flames, and red-hot objects which we see by their own direct rays. They are called luminous bodies.

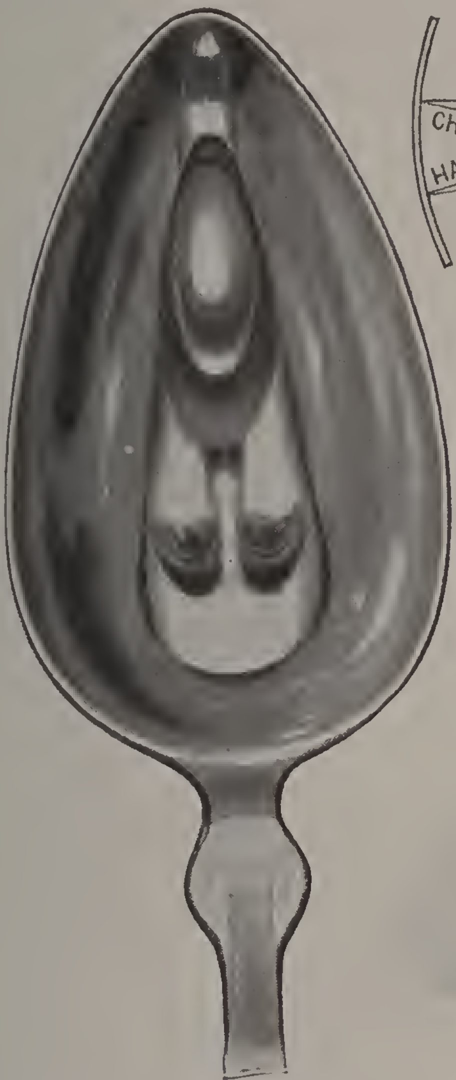


How the light, in reflecting an object, falls on a mirror.

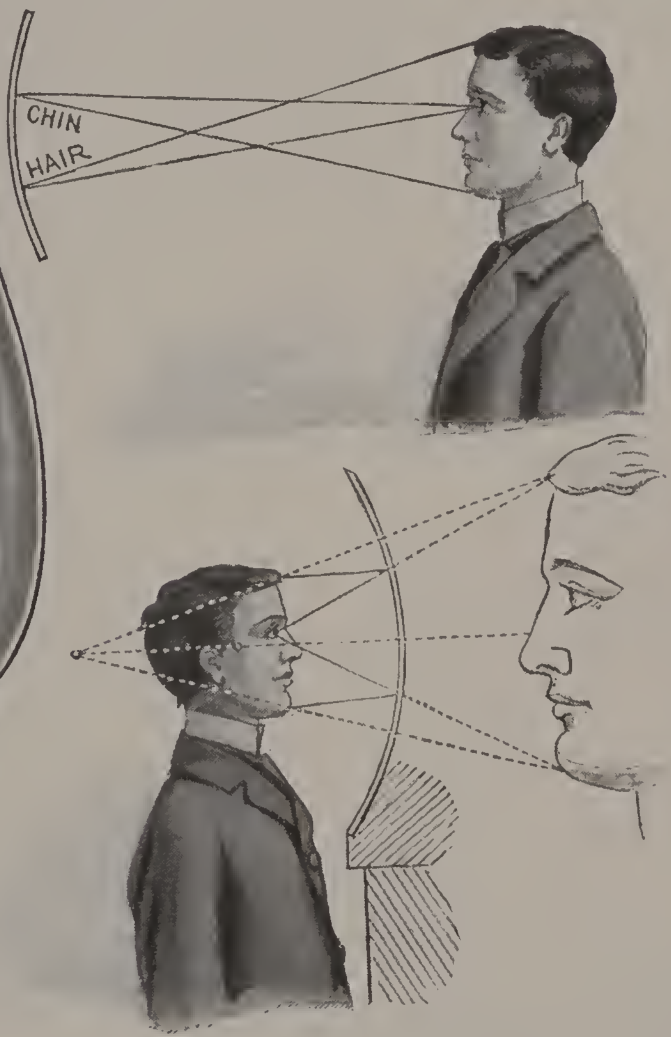
"Aren't stars luminous bodies too?" inquired Tom.

Yes, they are suns like our own, but they are so far away that they appear small to us. Venus and Jupiter are called the evening and morning stars, but they are not really stars. They are planets or worlds like our earth. They are seen, as the moon is, by the light of the sun reflected by them.

"Don't we see ourselves in a looking-glass by reflected light?" asked Amy.



Distorted reflected image.



How the light, in reflecting an object, falls on a curved surface.

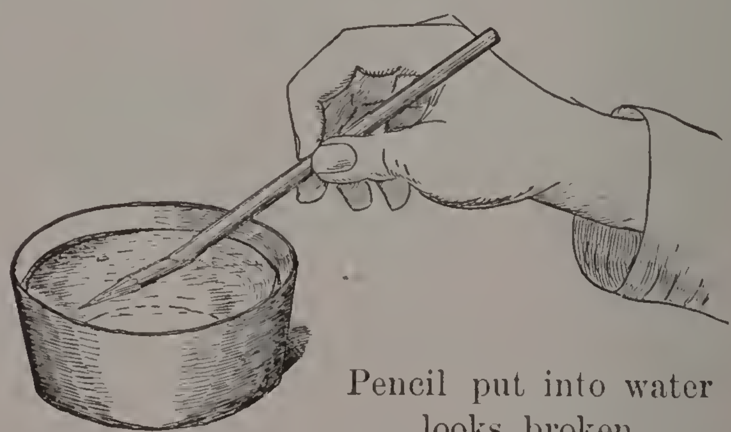
Yes, the rays of light from every part of your face fall on the surface of the mirror, from which they are reflected to your eyes. We see the image in the direction in which the rays enter our eyes. Do you think there is a real image formed behind the mirror? How far does it seem to be behind the mirror? Can you draw lines to show how the image is formed? Trees and other objects near a pond or a quiet river are often reflected so as to make a beautiful picture.

When the reflecting surface is unequally curved, the image is often distorted. Look in a polished spoon or silver vase.

LIGHT IS REFRACTED.

Willie showed us proof that light moves in straight lines. Reflected rays are no exception; they are rays turned from their course by a polished surface. Is there no exception?

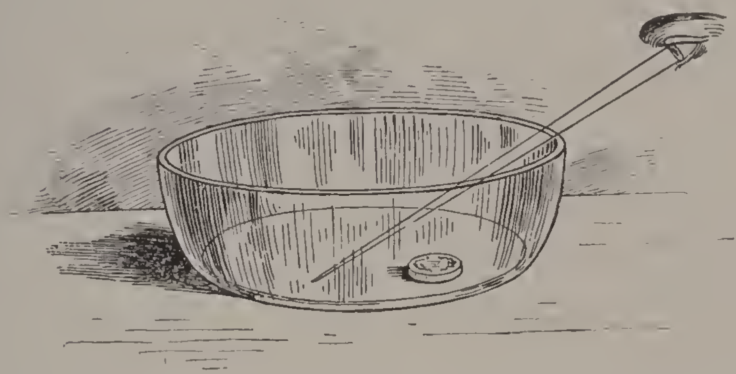
Look at my pencil point under water.



Pencil put into water looks broken.

"The pencil looks broken at the water," said Amy.

You are sure the pencil is not broken ; the light must be playing a trick with us, but we shall find out its tricks. Let us put a penny in the dish and you



A penny in an empty dish. Looking from the position occupied by the eye the penny can not be seen.

put your eye a little distance from the pan, so that looking over the edge you can not see the penny. Now I will pour water in slowly.

"Now I can see it," said Tom.

A penny in a dish containing water becomes visible by the refraction of the rays of light.

As you can see by the drawing, the penny has not changed position; neither has the eye. The rays come from the penny toward the eye, and at the point where they leave the water and enter the air they are bent or broken, and then in that direction pass into the eye. The eye sees an object in the direction in which the light enters it.

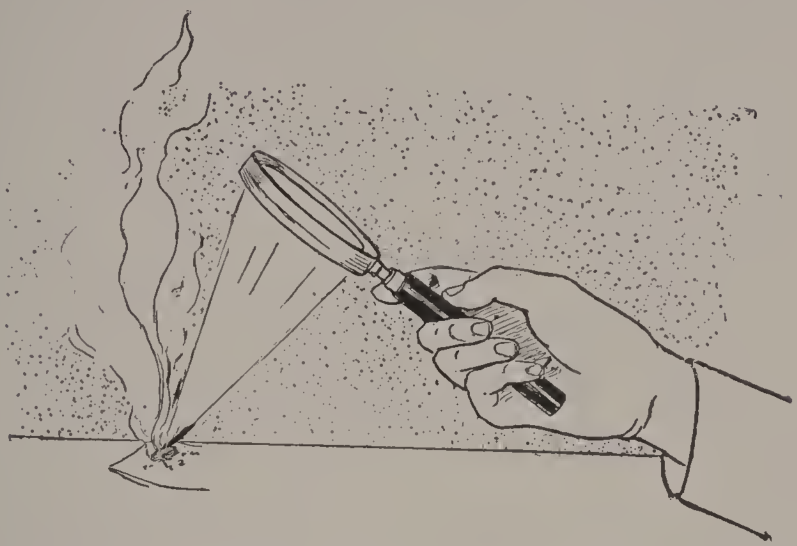
A fish is not where you see it in the water. Will you have to aim higher or lower than where it appears to be if you want to shoot it with a rifle?

Try the penny experiment by looking vertically down upon it, then more and more obliquely. At which position do the rays bend most? This bending of the beam of light is called refraction (broken).

Anything through which light passes is a medium of light. Air is a medium of light; water is also a medium of light, and so is glass and any other substance through which the light can pass. Such substances are said to be transparent (*trans*, through, and *parent*, appearing). Bodies through which the light shines, but through which we can not see objects are translucent (*trans*, through, and *lucent*, shining). Bodies through which the light does not shine are opaque (dark).

Double-convex lens and plano-convex lens.

When the medium is thin like air it is a rare medium. Water is a denser medium than air, and glass is denser than water. The light from the penny to the eye passed from a denser to a rarer medium, and the beam bent away from the



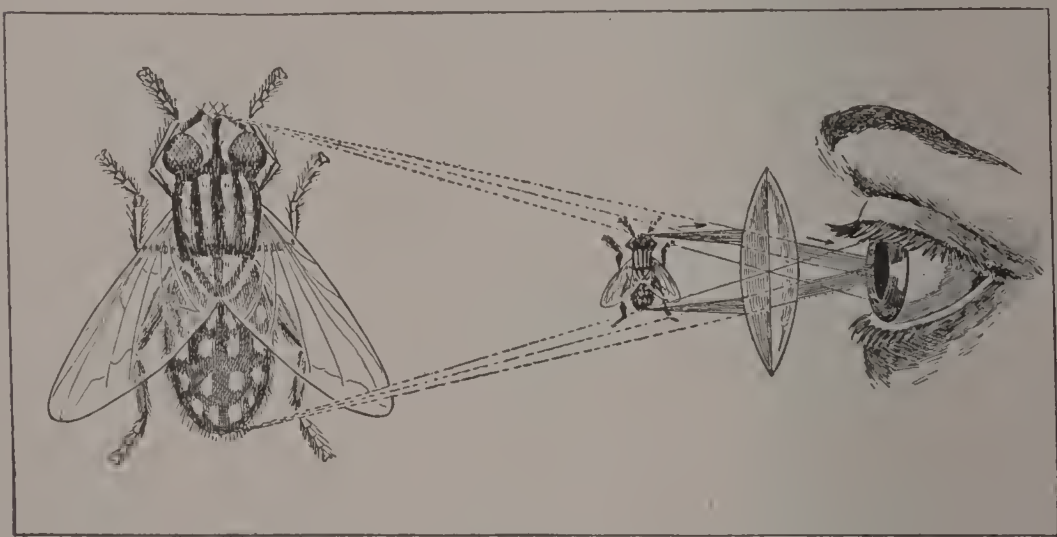
Burning glass, showing how the rays of light shining through the glass concentrate upon one point which they heat sufficiently to ignite if the surface they fall upon is combustible.

perpendicular. When light passes from air into glass or any denser medium it is bent toward the perpendicular. For this reason refraction is a very important property of light, as you will soon see.

A lens is a glass usually circular in shape. The surfaces are planes, convex or concave. In the illustration you can see a double convex and a plano-convex.

In the next illustration you can see a double convex lens, often called by boys and girls a burning glass. The rays come in parallel lines against the lens as they enter it. They are bent toward each other, and as they pass out on the other side they are bent still more toward each other, and meet in a point which is called the focus. The rays only slightly warm the lens, but at the focus they are hot enough to set paper and even wood on fire.

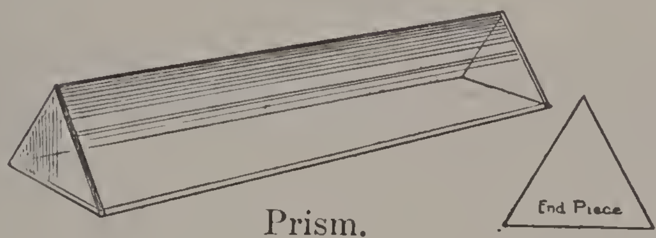
I have read an account of an arctic explorer who once had no matches with him, but who made a large lens out of a piece of ice, and by using it as a burning glass, succeeded in getting a fire.



A fly magnified by a lens.

If a little bug or a fly is placed at the focus of a lens, it will appear much larger to one looking through the glass. Can you tell why?

There is another instance of refraction most interesting. It occurs when light passes through the corner of a glass object. A triangular prism of glass may be used. You can make such a prism by having the glazier cut three pieces of glass each five inches long and one and a quarter inches wide, and



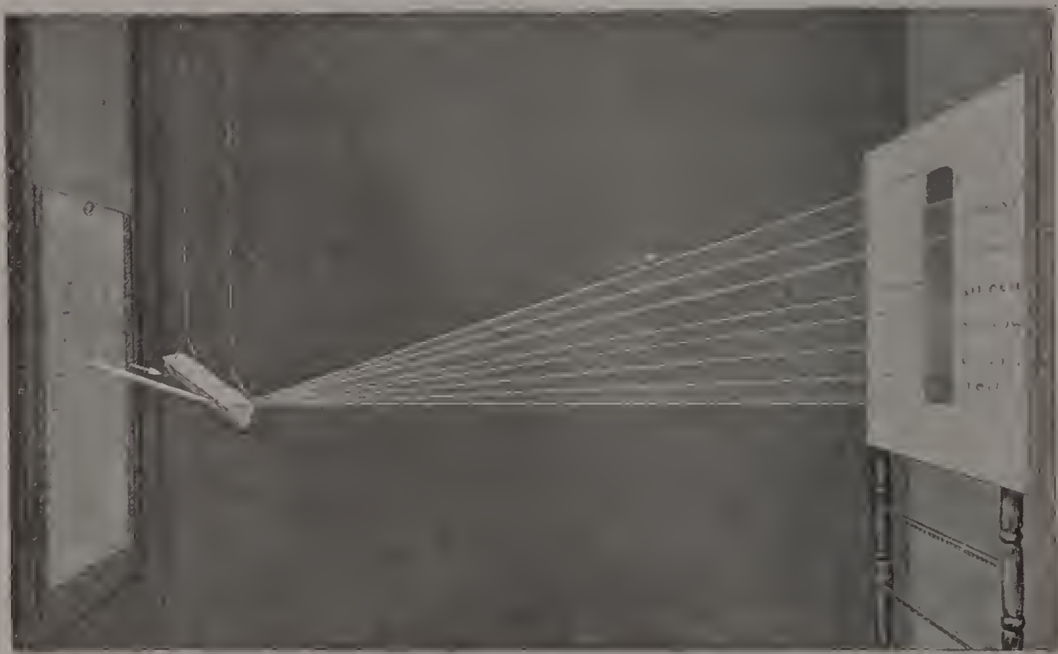
Prism.

two three-cornered pieces each side an inch and a quarter in length. They can be fastened together with a little cement and filled with water. The prism must be put in the path of the beam, so that the colors will fall on the white screen, as shown in the picture.

"Isn't that beautiful!" exclaimed Amy. "I see violet, blue, green, yellow, orange, and red."

There are two shades of blue and two of yellow; the first blue is indigo, and the second yellow is orange. The first letters of the colors spell the word *vibgyor;* that will help you to remember them.

When the beam enters the glass it is refracted, and as it passes out it is again refracted. Isn't it wonderful that sunlight, which appears white, is really a mixture of seven bright colors? The red part of the beam is bent least from its course; the orange is refracted more, the yellow still more, and so on, the violet being most refracted. As some colors are bent more from their course than others, they appear one above the other on the screen. This



The prism in the path of a beam of light producing the seven colors on the screen.

separation is called dispersion of light. The double refraction will help us to understand the cause of the rainbow.

To see a rainbow you must be on the same side of the rain as the sun. The beam enters the drop, is refracted, and passes to the side of the drop opposite to you, where it is reflected and comes forward again to the lower part of the drop. Here it is again refracted and dispersed so that you see the colors. There are two refractions, one

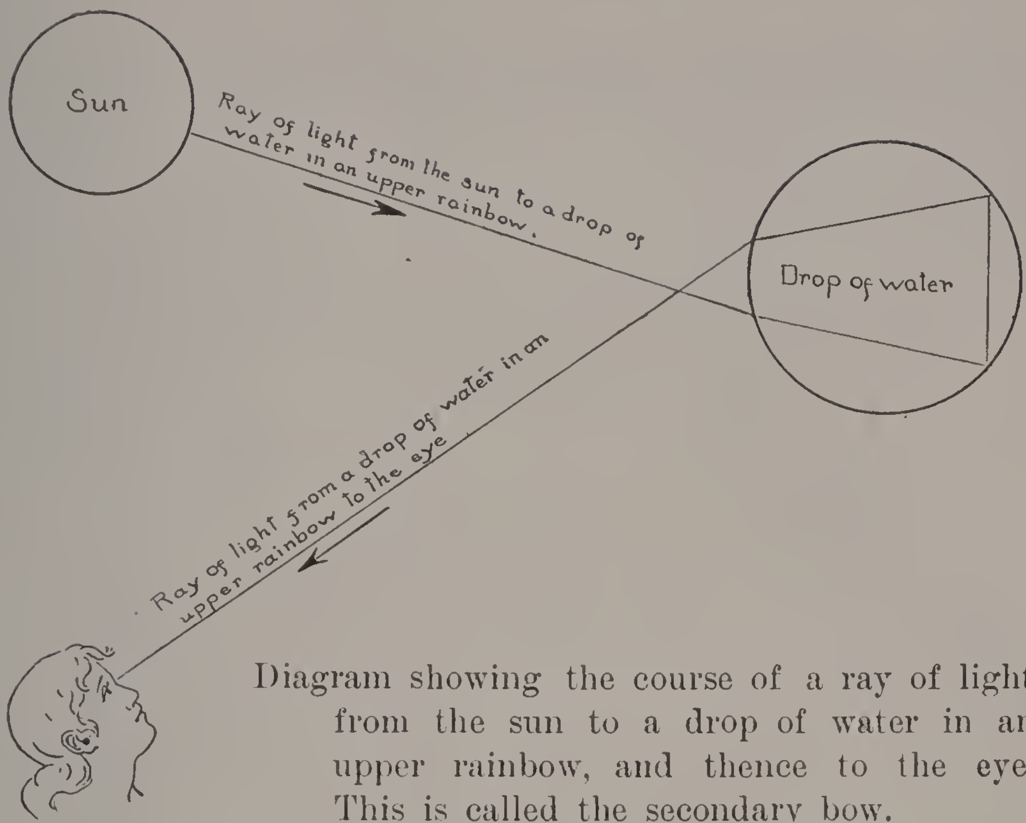


Diagram showing the course of a ray of light from the sun to a drop of water in an upper rainbow, and thence to the eye. This is called the secondary bow.

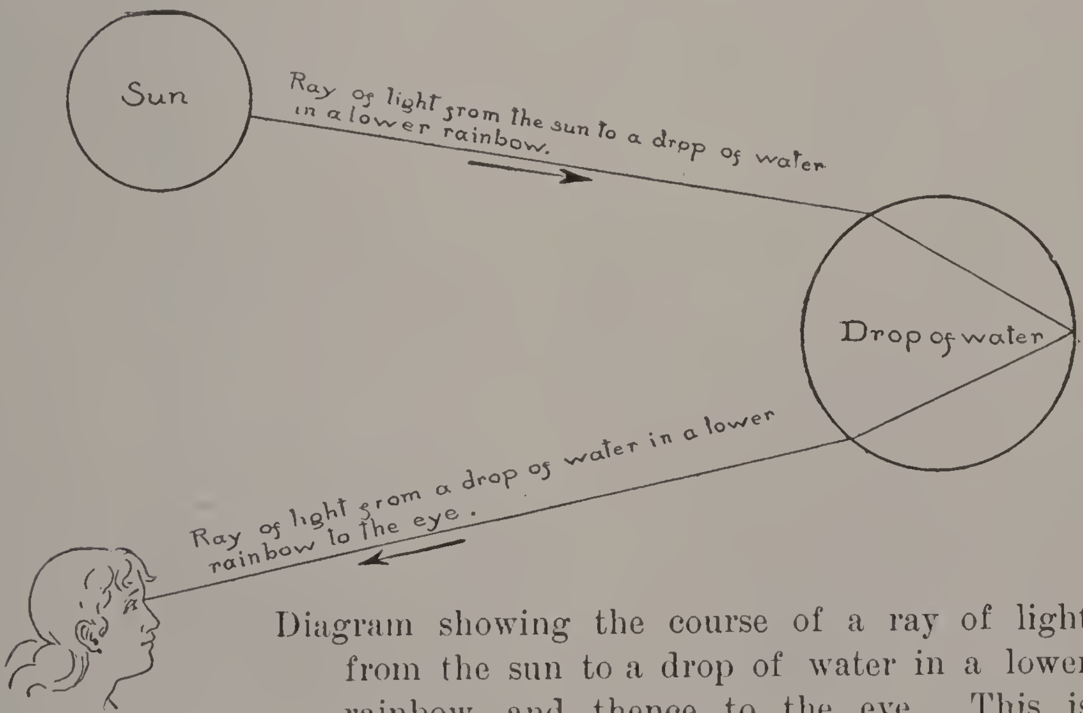


Diagram showing the course of a ray of light from the sun to a drop of water in a lower rainbow, and thence to the eye. This is called the primary bow.

A rainbow. In order that the two preceding diagrams may be better understood, a representation of the double rainbow is here presented. Two drops of water enlarged to the width of the bows show, as in the two preceding diagrams, the path taken by the rays of light from the sun to the two rainbows, and from the bows to the eyes of the spectator.

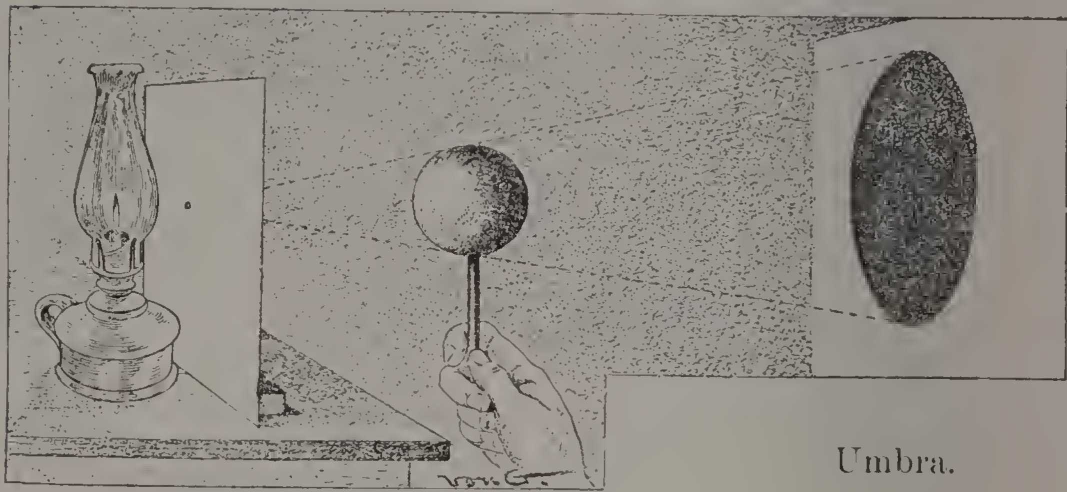
reflection and one dispersion in forming the rainbow.

You will see the colors dispersed by only those drops which lie in the proper angle of refraction—that is, the light from the drop to your eye must make the proper angle with the light shining on the drops. For this reason the colors appear only in a small band, two degrees in width, and that band in a circle. For the same cause no two persons ever see the same bow. Often a double rainbow may be seen. The second rainbow is formed by the rays that fall on the lower part of the drops, as you can see in the figure. The rays are then refracted, twice reflected, and again refracted before they pass to the eye. As a part of the light passes through the drop at each reflection, the second rainbow is fainter than the primary.

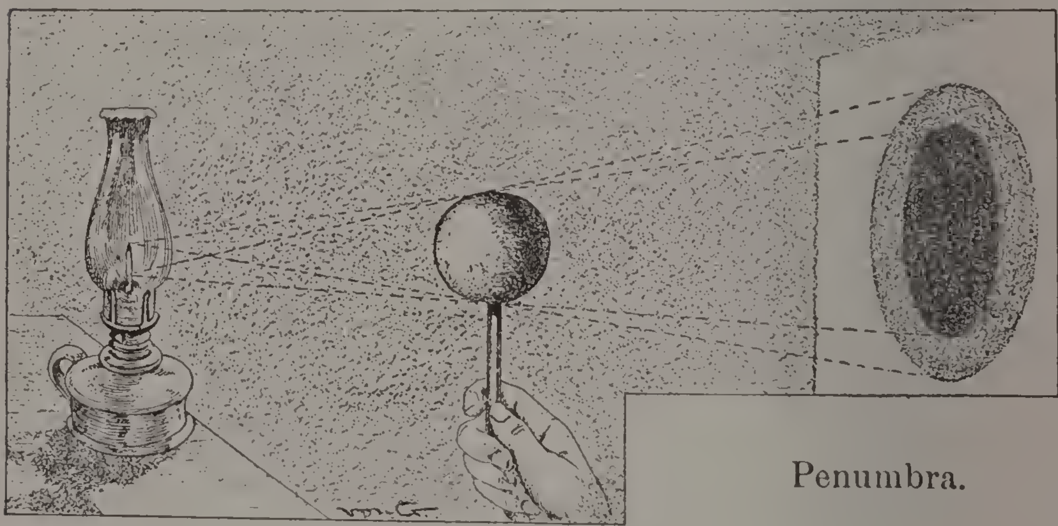
The rainbow colors may also be seen on soap bubbles, and when you are rubbing a moist finger over a window-pane.

UMBRA AND PENUMBRA.

"WILLIE and I tried an experiment last night," said Tom. "We stuck an orange on a lead pencil and held it up between the lamp and the white wall. It made a round shadow on the wall, and around the shadow was a circle of a lighter shade. Willie cut a small hole in a piece of cardboard and held it close to the light between the flame and the orange.



Umbra.



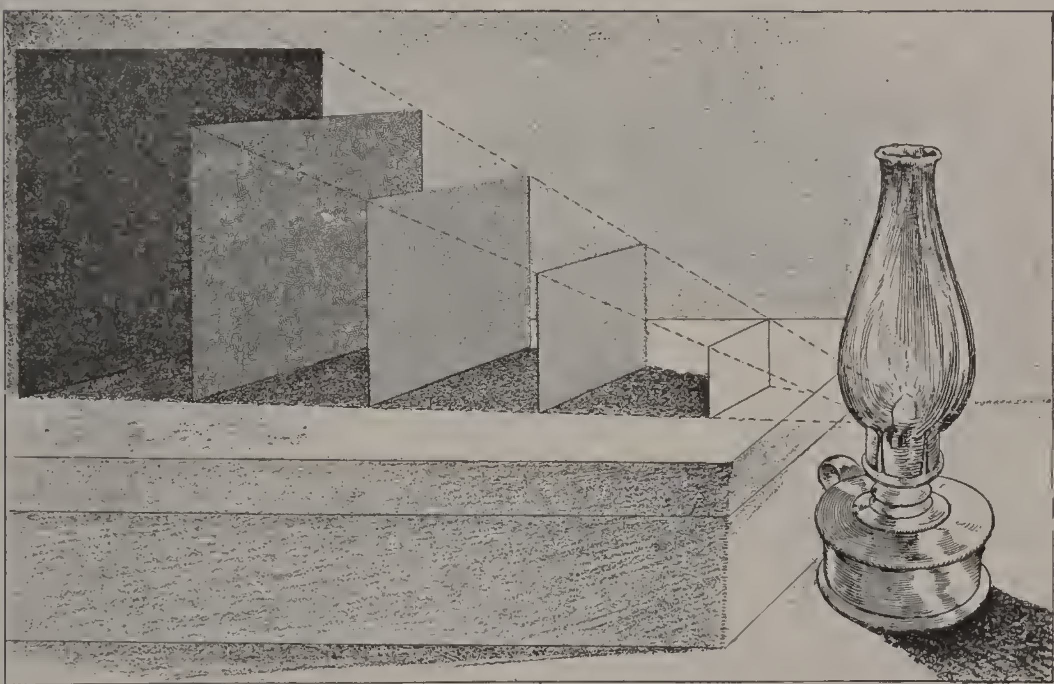
Penumbra.

This shut off all the light of the flame except that which came through the hole. The shadow now was dark all over. Then we concluded that the flame was so large that, in the first experiment, some of the rays shone around the orange into the shadow."

You have the correct idea. The shadow is called the *umbra*, which means shadow. The ring less deeply shaded is the *penumbra*, which means almost a shadow.

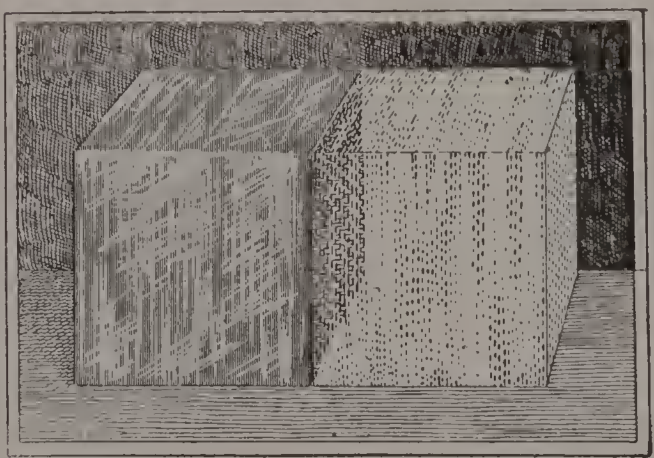
INTENSITY OF LIGHT.

"We made another experiment," added Willie. "We cut five squares out of pasteboard; one measured an inch on a side, the second two, the third three, the fourth four, and the fifth five inches on a side. Then we fixed the one-inch square up near the



Intensity of light.

flame, and placed the second card behind the first, just far enough away to be covered by the shadow of the first. We placed the third in the same manner behind the second, and so the fourth and the fifth. Next, we measured the distance that each was from the flame, and found that the second was twice as far away as the first, the third three times, the fourth four times, and the fifth five times as far away from the light as was the first. The light which shone on the one-inch square had to cover two times two or four square inches twice as far away, and three times three or nine square inches three times as far away, and so on. At five times the distance it had to cover twenty-five square inches. It seems to me the light would be only one fourth as strong two feet from the lamp as it is one foot away, because the same amount of light must cover four times as much space; at three feet it would be only one ninth as strong as at one foot; at four feet one sixteenth, and at five feet one twenty-fifth as strong, and so on."



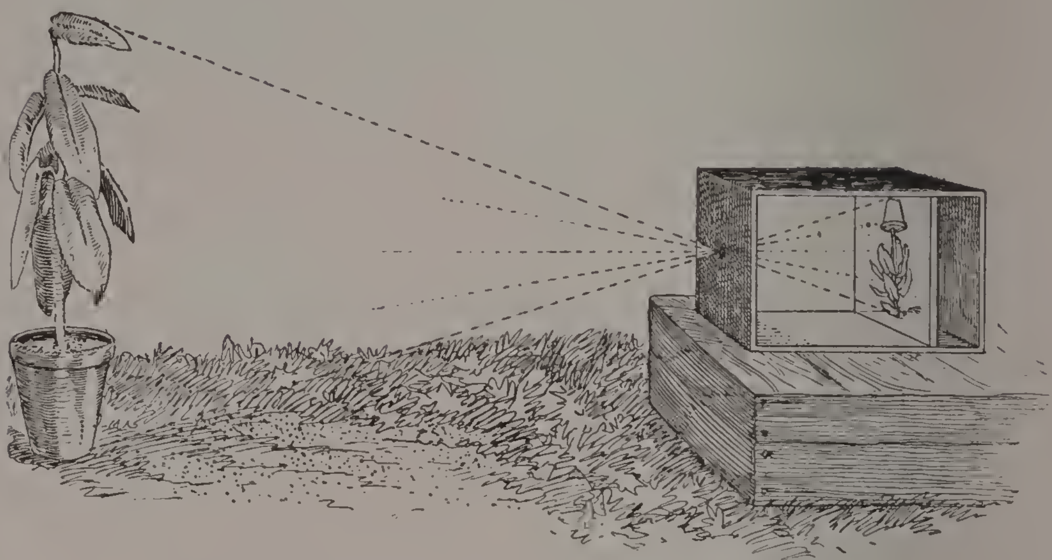
Simple apparatus for determining the comparative intensity of light.

That was a good experiment and you learned a fine lesson. A card with a hole in it placed nearest the lamp will make the shadows more distinct. Here is a very simple little thing that all of you can make. It shows which of two lights is the stronger, and you can find the point between them at which the light is equal. It is made of paraffin, which can be had of any druggist for a few cents. I cut two inch-cubes of paraffin with a hot knife. Then I warmed two faces of the cubes and stuck them together with a piece of thin black paper between them. When this is held between two lights, you can easily see which is the more intense.

INVERTED IMAGE.

"I HAVE a camera, and when I focus it the picture on the ground glass in the back is always upside down and right side to the left," said Willie. "How does that come?"

Here is a picture which will make that clear to you. At the right is a dark box so that the picture can be seen, with a small hole or aperture in the front side. From a point at the top of the plant light is reflected in all directions, but only one ray can enter the aperture of the box, and that strikes the back at the bottom. In the same manner, a ray of light comes from a point at the foot of the plant and strikes the back near the top, crossing the other ray in the opening. Thus you can trace a ray from every point in the scene to the back of the box or camera where the picture is outlined. All these rays cross each other in the aperture, and form a cone of light



A camera, showing inverted image.

on the outside with its apex in the opening, and another but much smaller cone inside of the box, because the distance between the aperture and the picture is much less than that between the aperture and the plant.

THE EYE.

"Isn't the eye still more wonderful than the ear?" inquired Willie.

Examine the eye and then you may decide for yourself which is the more wonderful. If you will look into each other's eyes when the light is dim, and then when the light is strong, you will discover something. Amy, you and Tom look into each other's eyes in this dim light.

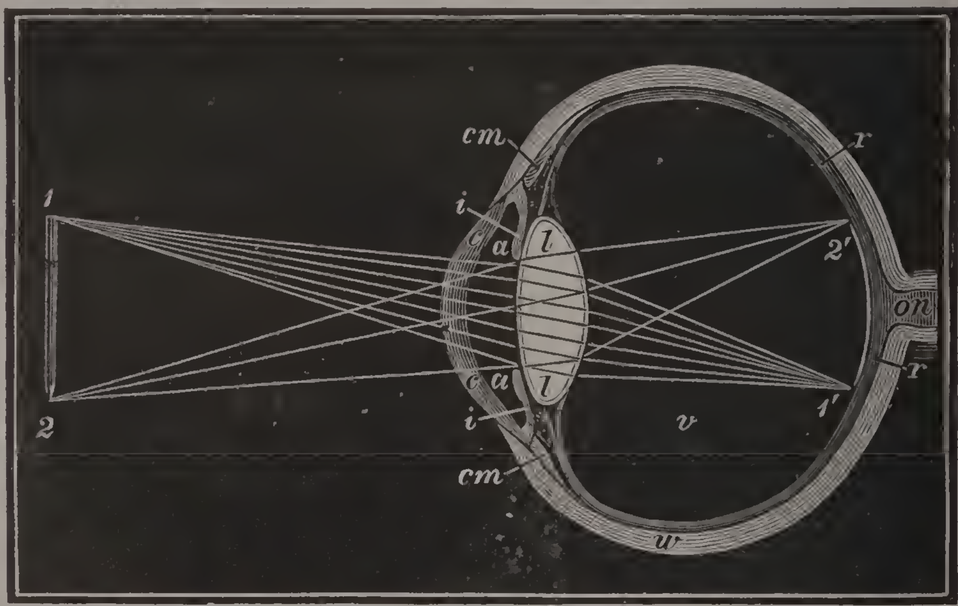
"I see a round dot in the center almost as large as a lead pencil. Next to this is a ring of brown, and then the white," observed the little girl.

Eyeball seen from the front. (After Le Gros Clark.) *w*, white of eye; *i*, iris; *p*, pupil.

"That is what I see in Amy's eyes," added Tom, "except that there is blue in her eyes instead of brown. I also see long lashes on her lids. Those on the upper lid curve upward. When she opens her eyes the upper lids make folds. I think her eyebrows are beautifully arched."

After looking at each other's eyes in strong light, both declared that the center, called the pupil, was much smaller. They believed that there was a circular curtain in the eye which in the strong bright light was drawn together so as to make the center or pupil smaller.

The eye is in some respects like the dark box shown in the picture of the inverted tree. It is nearly round; that is, globose in shape. The outside coat is very tough and white except in front. It is called sclerotic (*scleros*, hard, firm).



Section of an eye looking at a pencil. (Adapted from Kirke.) *c*, *c*, cornea; *w*, white of eye; *cm*, ciliary muscle; *a*, *a*, aqueous humor; *v*, vitreous humor; *i*, *i*, iris; *l*, *l*, lens; *r*, *r*, retina; *on*, optic nerve; *1*, *2*, pencil; *1′*, *2′*, image of pencil on the retina.

Willie, who always wants to see everything for himself, had brought a calf's eye which he obtained at the market. He now proceeded to dissect it, and explained its structure as follows. He said:

"The eye is round like a ball, but in front it bulges out a little. The front is the cornea. I will cut the eye crosswise. You see it is full of a clear, watery jelly. Now look through the front half. See the circle where the wall is transparent. The rest of it is opaque. Here is the lens, isn't it a beauty? In front of the lens is a small chamber full of a liquid like water.

"In this chamber just in front of the lens is the little curtain called the iris, on account of its different colors. Iris is the Greek word for the rainbow. This iris is bluish. A brown iris makes a brown eye, and a blue iris a blue eye.

"Now we will take the back half. See the black lining it has. How easily it tears. I will wash it all off. See the nerves spread out from the center. This cord at the rear enters the eye through the wall, and then is divided into fibers, and these form a lining on the inside of the eye. Here is the white spot where the nerves come through.

"I have a lens here, which I took out of another eye yesterday and put in alcohol. The alcohol has made it harder, but it is not so clear. Let me cut into it. There are different layers. How distinct they are."

Thank you, Willie. Here is a picture showing a cross-section of the eye from front to back.

The light enters the eye at the transparent front, the cornea, passes through the watery humor, and as much as the iris will permit goes through the lens and through the glassy humor, and, if the eye is good, is focused on the black lining. This makes an impression, which is carried to the brain by the white nerve.

As the light passes through the humors and the lens it is refracted slightly, least by the thin humor and most by the lens. You see the eye is similar to a photographic camera. The nerve or retina takes the place of the sensitive plate. The image is inverted as the tree was, but we do not see it so, as we have doubtless learned by experience how to interpret images.

In a camera we push the lens backward or forward until we get a good, clear, inverted image on the ground glass where the plate is to be. But the eye must do its own focusing. The shape of the eye is changed by the muscles so as to make the image focus on the retina. It requires a little time to do this, as you will discover for yourself if you look at an object far away, and then quickly at one close to the eye. You will not be able at once to see the one near by.

Now you may each take a book and read. How far must you hold it from your eye to see the print most easily? Let me measure. Willie, your book is eleven inches away from your eyes; Amy, yours is ten; and Tom, yours is only six inches. You are short-sighted. The cornea, and perhaps the lens, of your eyes is so convex that the rays are brought to a focus before they reach the retina. In order to make them focus on the retina the book must be held very close to the eyes. You ought to have glasses so that you would not strain your eyes and thus weaken them. You notice that Tom half closes his eyes

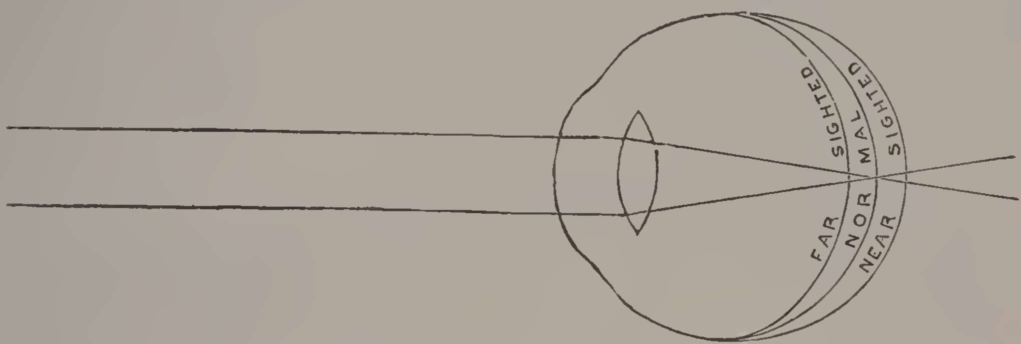


Diagram showing the point at which the rays of light are brought to a focus. In a far-sighted eye the globe is too short, and in near-sighted the globe is too long.

when he wants to look sharply. Near-sighted persons usually do that, and for this reason short-sightedness is called *myopia* (two Greek words meaning closed eyes).

"I have often seen old people hold objects far away when they wanted to see them," said Willie. "Isn't that because the cornea or lens is too flat and the image is formed behind the retina?"

Yes, that would be the case if the rays could pass through the retina; but as they can not, there is no image formed at all. Convex glasses will help such eyes to focus properly. Long-sightedness is called *presbyopia* (two Greek words meaning old-man eyes), because in old age the muscles get shorter and thus flatten the eye. It is claimed that this can be avoided if you practice daily looking at an object before you and then turn your eyes to look at one above, then below and back again, and so to the right and back, and to the left and back, and likewise in the oblique directions, so as to exercise all the muscles that move the eyeball.

I have two objects of the same diameter. I will not let you see them until I have placed them directly opposite the window. Now, look and tell me their shape.

"They are little white disks," responded Tom.

"I think they are hemispheres," ventured Willie.

Then I placed them so that the light fell upon them obliquely, and at once both concluded that one was a disk and the other a hemisphere. They were made of plaster of Paris and carefully molded, so that no shadows would appear on them when the light fell directly upon them. I think that we are not always able to recognize the form of objects by the sense of sight without the sense of touch.

"Would there be light if there were no eyes to see?" inquired the young scientist.

I believe it is the mind that sees and not the eye, but the mind can not see without the eye. The mind sees not the light, but only the image which the light makes on the retina. There must be many images on the retina at one time, but the mind selects the one it desires to attend to. We pass many objects daily whose images fall on the retina of our eyes, but we do not see the objects, or rather we do not examine their images, and hence we do not know anything about them. We must have a desire to see before we shall see.

It is by means of the eye that we get a knowledge of color, and to a large extent, of the form of objects. Think, if you can, of all the shades and tints of green, of red, of yellow, of blue; they are nothing but light, more or less according to the colors reflected. You remember the spectrum of the seven colors made by the sunbeam as it passed through the prism. The red color is a part of the sunbeam, and so are the green and the blue. When we see a red object, what do we see? Nothing more than the red part of light. What becomes of the rest of the light? That, I think, is taken in or absorbed by the object. When I rub green chalk on this paper, I put a surface on it that will reflect the green part of the light only.

"Our teacher in drawing said that foliage is not pure green," put in Tom. "She said it is of various shades of color, according to the plant to which it belongs and the kind of light that shines upon it."

That is correct, but you are an investigator and ought to find out for yourself by drawing a leaf with green chalk or paint, and then laying the leaf beside it.

"Can the eye be trained as well as the ear?" inquired Willie, and then he proceeded to answer his own question. "I know that I can distinguish tints much better now than I could before I began to draw in colors."

Some persons are unable to distinguish some of the colors from others. I knew a boy who could not tell whether an object was green or red. Such persons are said to be color blind.

"What is light?" asked Amy, who had been urged by Willie to do so.

To answer we must go outside of the domain of science, for science deals only with facts, conclusions which can be demonstrated, but scientists can not keep from philosophizing; that is, reasoning and thinking about the facts.

We can see some of the effects of light and heat, but we can not see what they are themselves. We begin to reason about them and try to make up an explanation that may fit the facts. Such an explanation is called a theory. So we have a theory of sound. It is supposed to be a wave motion of air or other substances through which it passes. Heat is a wave motion, not of air, but of something that is much thinner and without weight—ether. Heat waves are much shorter than sound waves. Light is supposed to be ether-wave motion also, but the waves are very much shorter than those of heat. If we heat iron it may be so hot that we can not touch it, but still remain dark. Heat it more and more, and it will become red; and if we continue to heat it in a hot fire, it will become still brighter until it gives out a white light. The light waves are not only very short but are supposed to travel so rapidly that millions rush into the eye every second.

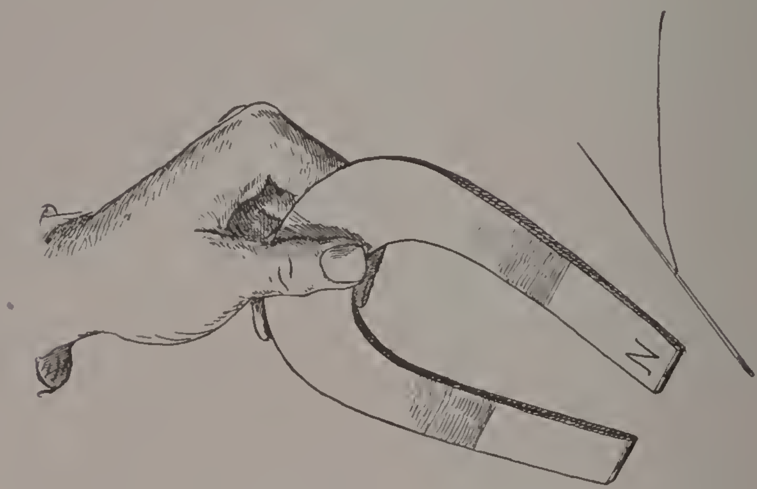
The theory is that violet light differs from red light in having more vibrations a second—nearly twice as many, in fact. Each color has its own number of vibrations, and the different shades are mixtures of two or more of these sets of vibrations. How wonderfully sensitive the eye must be to report these differences of wave motion so accurately to the brain!

MAGNETISM.

Two years ago we made some experiments with the magnet. We shall now see what else we can learn about it.

Tom, wishing to show us some experiments, suspended a large darning-needle by a thread, as you see in the picture. It of course swung round and pointed in no particular direction.

He held the magnet near the needle, and both ends

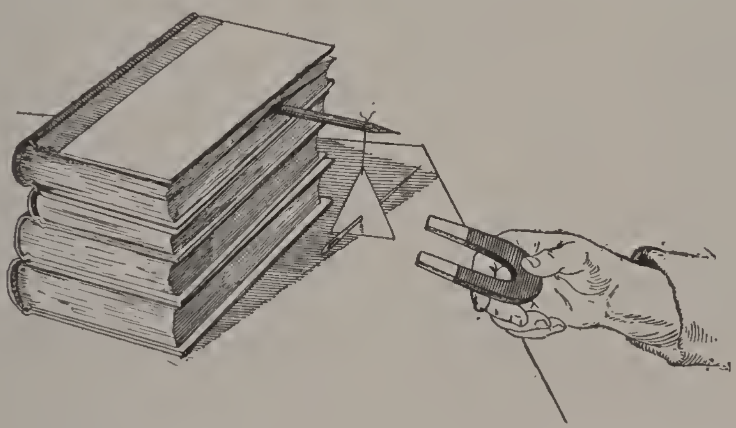


Needle repelled by magnet.

of the needle were attracted by the same end of the magnet. Then he laid the needle on the end of the magnet marked *N*, and drew it first over this end point. He did this six or seven times, and suspended it as before. The needle now pointed north, and when he brought the *N*-end of the magnet near it, the point of the needle was pushed away, or repelled, as we say, but the eye of the needle was attracted by that end of the magnet. Then he tried the other end of the magnet. It attracted the point, but repelled the eye of the needle. The magnet had evidently produced a change in the needle; it magnetized the needle.

Meanwhile Amy had magnetized another needle (it was an ordinary sewing needle) by drawing it over the unmarked end of the magnet. She did not suspend hers, but rubbed it between her fingers to make it oily and carefully laid it on the surface of a dish of water. It floated like a straw. This seems strange, for steel, of which the needle is made, is heavier than water, but a thin coat of air clings to the polished steel and the needle is not heavy enough to break through it to the water. If the needle is not dry it will not float. The needle soon turned so that the eye pointed to the north.

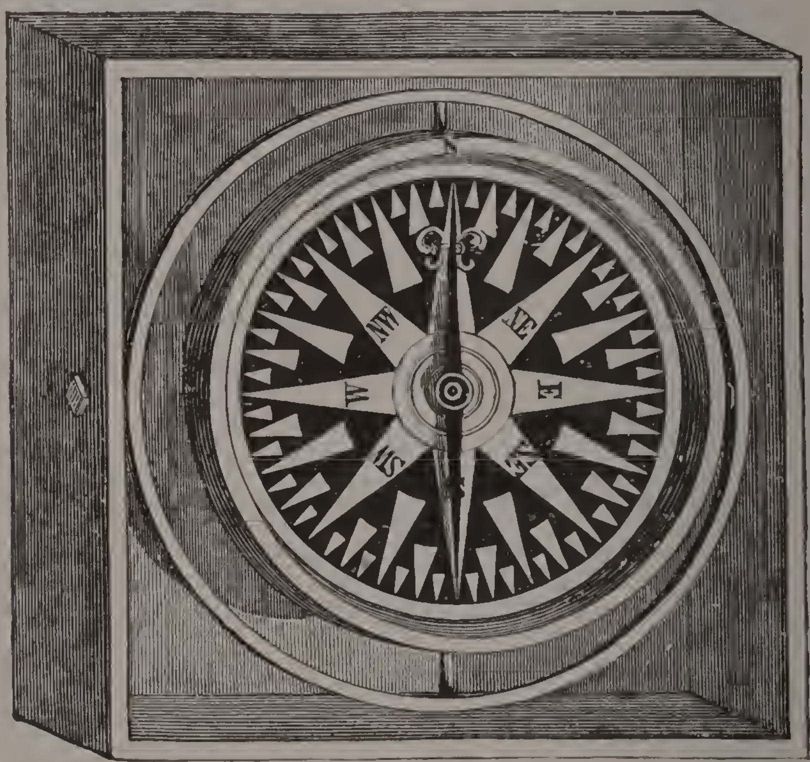
Tom next tried to magnetize a piece of iron wire, but there was no lasting effect. As long as the wire was held against the magnet, it turned the needles



Manner of suspending needle to be experimented with by a magnet.

brought near it, showing that it was magnetized as long as it touched the magnet. The magnet seemed to produce no effect on copper and brass; steel only remained magnetized.

The magnet has something in it that can do work; that is, it can move things or change them in some way. That which does work or produces an effect we call force. Force shows itself by means of many things. Force shown by muscle is muscular force; water flowing over a falls or a dam is water power; water changed to steam is steam power; when force shows itself in the magnet it is magnetism.



Mariner's compass.

When this force is transferred to a needle, the needle becomes a magnetic needle. Its two ends act differently, as you have seen. One end is said to have positive magnetism, and the other negative. I can not see any reason for these names, as one kind seems to be as positive as the other. The end of the needle which seeks the north is known as the north pole of the needle, and the other as the south pole.

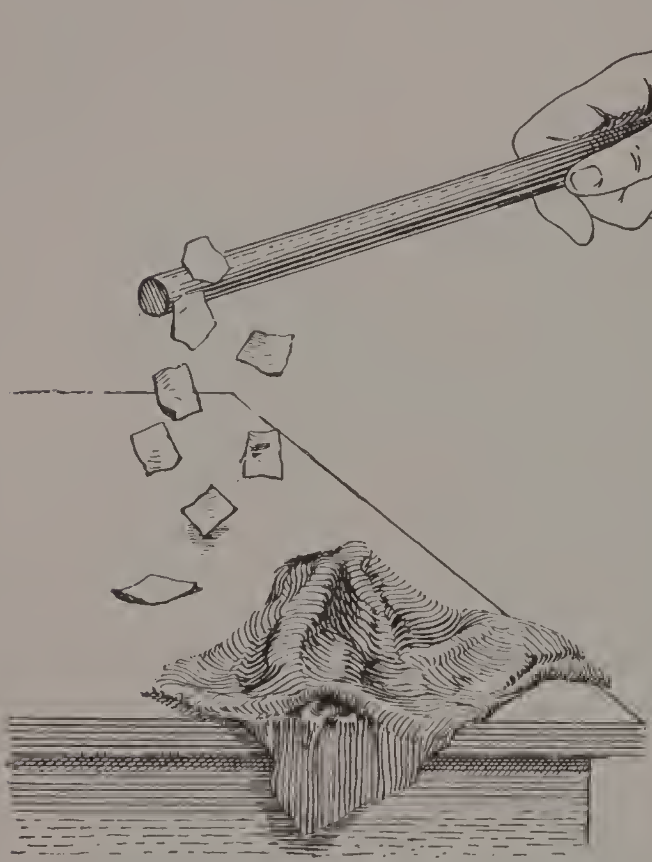
Scientists think the earth is an immense magnet because it seems to affect the needle just as our little magnet did. The north magnetic pole of the earth is located in the northern part of Hudson Bay. Wherever we may carry the magnetic needle on the earth, it points directly toward that place, unless disturbed by some magnetic minerals near by. You will see that the needle does not point exactly north in all places.

When the needle is suspended on a metal pivot and a plate on which the directions are marked is fastened under the needle, the instrument is called a compass. It is used by mariners and surveyors.

ELECTRICITY.

"I WANT to ask you a question," said Tom one bright winter's afternoon. "I was combing my hair this morning with a hard rubber comb. I laid the comb on some bits of paper which had been left on the stand, and as I put the comb down the bits of paper seemed to fly up against it. Can you tell me what made them do that?"

Yes; but before I answer your question, let us try several things. Here is a rubber comb and a piece of old silk. Now I will put the comb on these bits of paper; they lie perfectly quiet, but let me rub the comb briskly with the piece of silk, and then hold it near the papers.



Glass rod attracting bits of paper.

"Oh, see them jump up!" cried Amy.

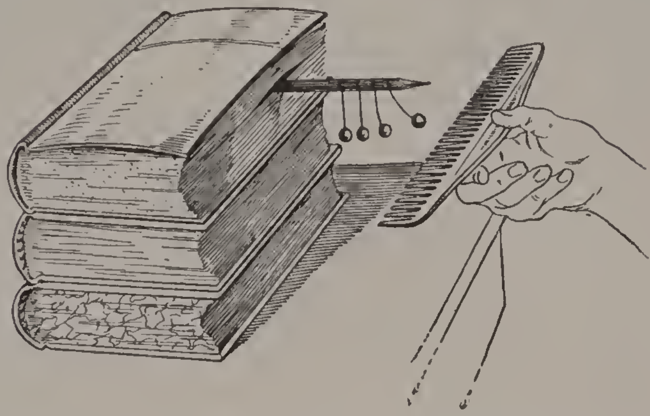
"They look as though they were alive," added Willie.

I will now use a glass rod instead of the comb.

"That does it too," exclaimed all the children at once.

Amy, you make two little balls about as large as a pea out of this cotton. Tom, you may get a silk thread about a foot long and fasten the balls that Amy makes, one at each end of the thread. I will hang them over the pencil fastened in this big book. Now I'll rub the comb with the silk and hold it near the cotton balls. Little sharp eyes, what do you see?

"When the comb came near the balls they flew at it, and then they flew back. The balls tried to get as far away from the comb as they could."



Cotton balls attracted by rubber comb.

"Why do they do that?" put in Amy.

We shall see. Now let me try the glass rod. See, the balls come toward it; but just as soon as they touch it, off they fly, and every time I bring the rod near to them they try to get away. But if I bring the comb near, they are drawn to it for an instant.

"I think the glass has something on it that draws the balls to it until they get full of the same thing," Willie offered as an explanation, "and when they are full they don't want any more."

The balls are like a greedy boy who has eaten so much cake that he can not bear to think of any more. But how is it that when I rub the comb and bring it near the balls, it attracts them?

"There must be a different kind on the comb," said Willie.

You are quite right. When the glass rod or rubber comb is rubbed something is developed that wasn't there before. It is a force, because it can do something. As you saw, it attracted the cotton balls at first and then sent them away. This force is called electricity—a word which comes from *electron*. Electron is a substance in which people of olden times first observed the effects of this force.

The force produced on the rubber comb or ruler by rubbing it, acts differently from that produced on the glass rod. When the balls touch the glass rod they get full of the same kind of electricity, and therefore are soon repelled. Then when the comb is brought near them they are attracted because it has opposite electricity.

When things are charged with the same kind of electricity they repel each other, and when they are charged with opposite electricity they attract each other, just as you saw in magnetism. When an object is full of electricity, we say it is charged with electricity.

FRICTIONAL ELECTRICITY.

The electricity produced by rubbing is called frictional electricity. I have often heard this electricity snap in my hair, when I passed the comb through it on a dry cold day.

"I've seen sparks in the dark when I rubbed my kitty's fur," said Amy.

"And I've seen them on my horse when I curried him," said Willie.

When I rub the glass rod with the silk, the friction produces one kind of electricity on the rod, and the other kind on the silk, as you will see if I hold the cloth near the balls. Now if I rub the comb with the same silk, the same kind of electricity that was on the silk before will now be on the comb, and the kind that was on the glass before will now be on the piece of silk.

Watch me rub this stick of sealing wax and try it near the balls. What do you think of the kind of electricity the wax has?

"It has the same kind as the comb," Tom quickly replied.

Now by rubbing other objects with silk, we shall find that on some of them the same kind is produced as on the glass, and on the rest the same kind as on the sealing wax. You can try many such experiments by yourselves.

We call the electricity produced on the glass by rubbing it with silk, vitreous electricity, and that produced on the sealing wax, resinous. Vitreous means of glass, and resinous means of resin or wax. More often we call the vitreous *positive*, and the resinous *negative* electricity, and write them as + and — electricity.

Now, Tom, you can answer your own question about the comb and the bits of paper.

We also rubbed the glass with linen cloth; but little effect was noticeable, and, what there was, soon disappeared. There was even less effect noticeable when the glass was rubbed with the hand.

When the glass was moistened or the silk damp, no effect was seen. Why was this?

I think there was just as much force produced on the rod with the linen or the hand as there was with the dry silk, but the force flowed off the linen rapidly. Over glass or rubber it seems to pass slowly, so that it can collect in sufficient quantity to produce noticeable effects. When the cotton balls were suspended by linen instead of by silk thread, they were charged just as those on the silk thread were, but they soon came together, showing that the force had passed from them over the linen.

Objects which do not hold electricity are called *conductors*, and those over which it passes very slowly are *non-conductors*. Linen, water, and the hand, are good conductors of electricity ; glass, rubber, and dry wood are poor conductors.

Frictional electricity is produced by machines in considerable quantity. A person may hold his hand on one of these machines and let the electricity pass through his body without any effect; but if he stands on a stool having glass feet, when the air is dry, his hair will stand out straight from his head. The glass feet of the stool prevent the force from passing to the ground.

"There is a friction machine at our high school," said Willie. "I held my knuckle near the knob, and when a spark over an inch long passed from the knob to my hand I heard a snapping noise and felt a sharp sting. The spark looked like lightning. Is it the same?"

Dr. Benjamin Franklin made some interesting experiments. He made a kite by fastening a silk handkerchief to a light cross constructed of two cedar sticks. At the upper point he attached a pointed wire about a foot in length. A key and a piece of silk ribbon were tied to the lower end of the twine. Then he waited for a thunderstorm. When it came he and his son let out their kite. Mr. Franklin stood

Dr. Benjamin Franklin's experiment with a kite.

inside of the door to keep the ribbon from getting wet. He took care that the twine did not touch any object. As the cloud stood overhead he saw by the fuzz on the twine that there was some force on it. He held his knuckle near the key and received a shock. He performed many other experiments with his kite, proving that lightning and frictional electricity are one and the same thing. He also found that sometimes the cloud was positively and at other times negatively electrified.

About the same time several men in France were experimenting along the same line, but instead of a kite they used an iron rod erected on the house. One day during a heavy thunderstorm they were watching their apparatus. Mr. Richman—that was the name of one of the men—had his head about a foot from the rod when his companion saw a ball of fire pass from the rod to Mr. Richman's head with a loud, crackling report. The stroke killed him instantly.

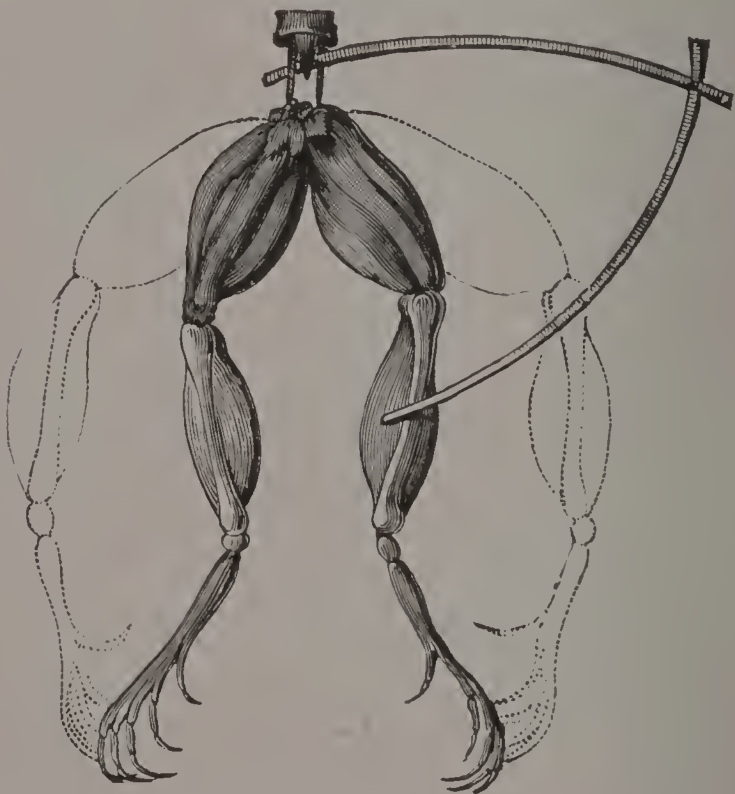
Mr. Franklin's metal point on the kite drew off the electricity slowly, and this led him to invent lightning rods.

"I have more than once noticed that it rained much harder after a loud clap of thunder," observed Willie. "Does the thunder have anything to do with it?"

I think not. The thunder does not produce the rain. It is rather a result of the rain. Dry air is a poor conductor. A cloud may be charged with one kind of electricity and the earth just below with another kind; but the dry air keeps them from coming together, or discharging, as we say. The rain begins to fall and makes a path part of the way; the discharge follows and leaps over the remaining dry air so quickly that the flash is seen before the rain reaches the earth.

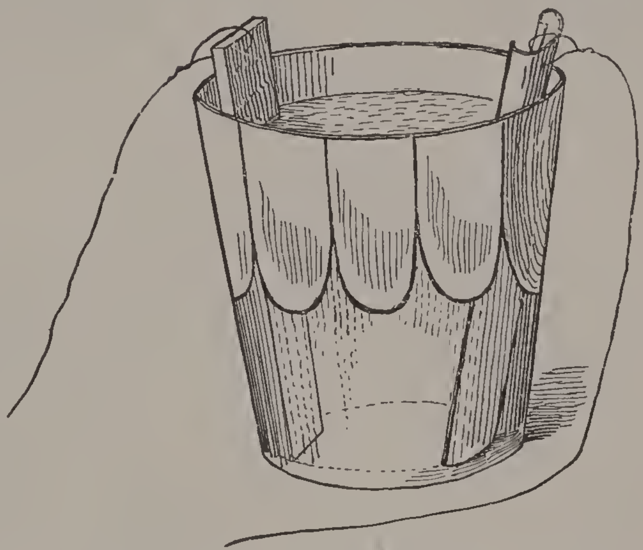
GALVANIC ELECTRICITY.

We are indebted to a dead frog for the discovery of another kind of electricity, and a most use-



Experiment with a frog's hind legs. Two wires of different metals touch each other at one end, while their other ends touch respectively the loins, and the nerves of the leg.

ful kind. His hind legs had been dressed to make part of a tempting meal, and hung on a copper hook. It happened that the hook was on an iron balcony so that the legs of the frog touched the iron. Professor Galvani's wife, so the story goes, noticed a jerking in the frog's legs and called her husband's attention to it. This led him to make other experiments, and he succeeded in discovering what has been called the galvanic current. Years later Professor Volta, also of the country of Columbus, made improvements in apparatus to produce it, and so it is sometimes known as voltaic electricity.

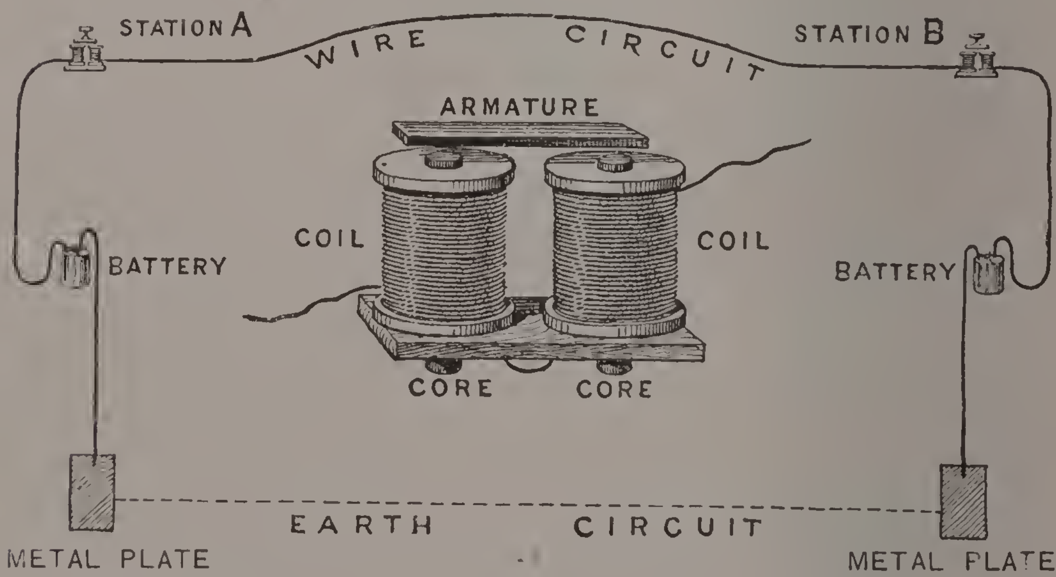


The simplest form of galvanic battery.

Then Tom, to whom I had suggested a little experiment, showed us what he had discovered. He said :

"This tumbler contains water into which I have put a spoonful of sulphuric acid. I have here two strips of metal; one is copper, the other zinc. I fastened a piece of copper wire to the top of each and placed them in the acid water, so that they did not touch each other. Now, when I join the wires and hold them near a magnetic needle, it makes the needle turn so that it stands almost across the wire. When the copper plate is nearer the needle it turns one way, and when the zinc plate is nearer it turns the other way. I put the strips into water without the acid and held the wire near the needle, but there was no effect; so I think there was something in the wire that came from the metals when the acid water touched them."

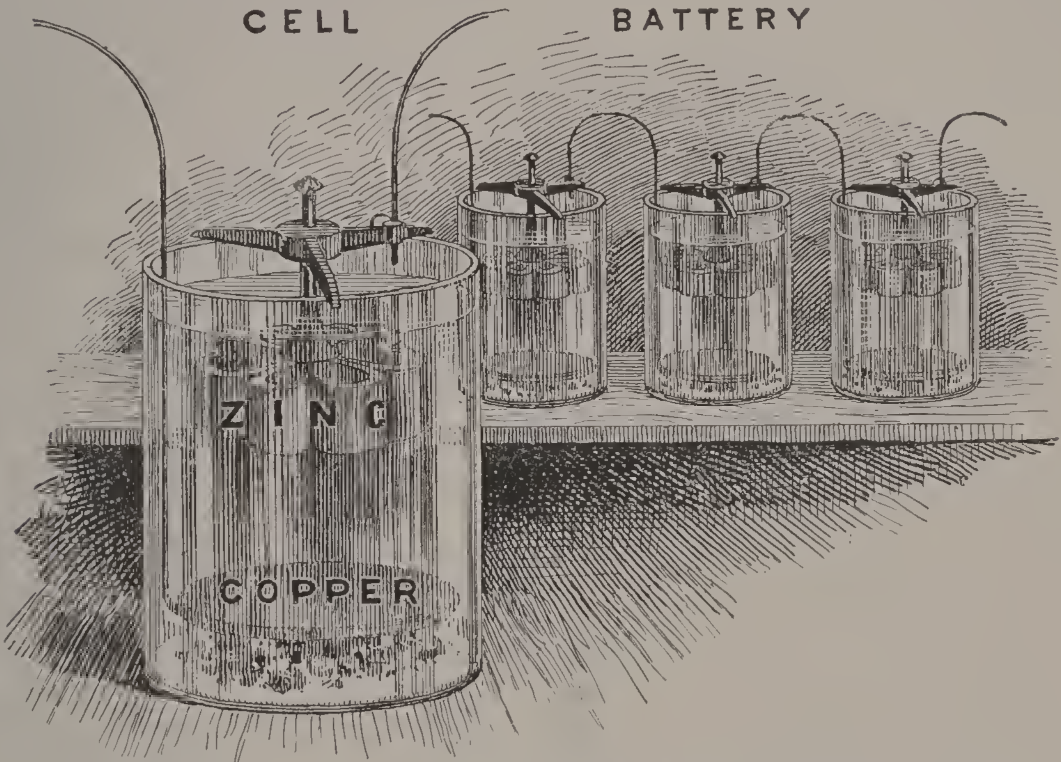
Your tumbler, Tom, is the simplest form of the galvanic battery. Some day you may place a penny on top of your tongue and a dime or nickel under it. Perhaps you can discover something.



The circuit of the telegraphic current.

"I think I can explain how the electricity was produced in the frog's legs," interrupted Willie. "The juices in the flesh of the frog took the place of the acid water, the copper hook and iron balcony the place of the metals, and the nerves the place of the wires."

Then Willie took Tom's battery and wound the wire through which a current was flowing around a



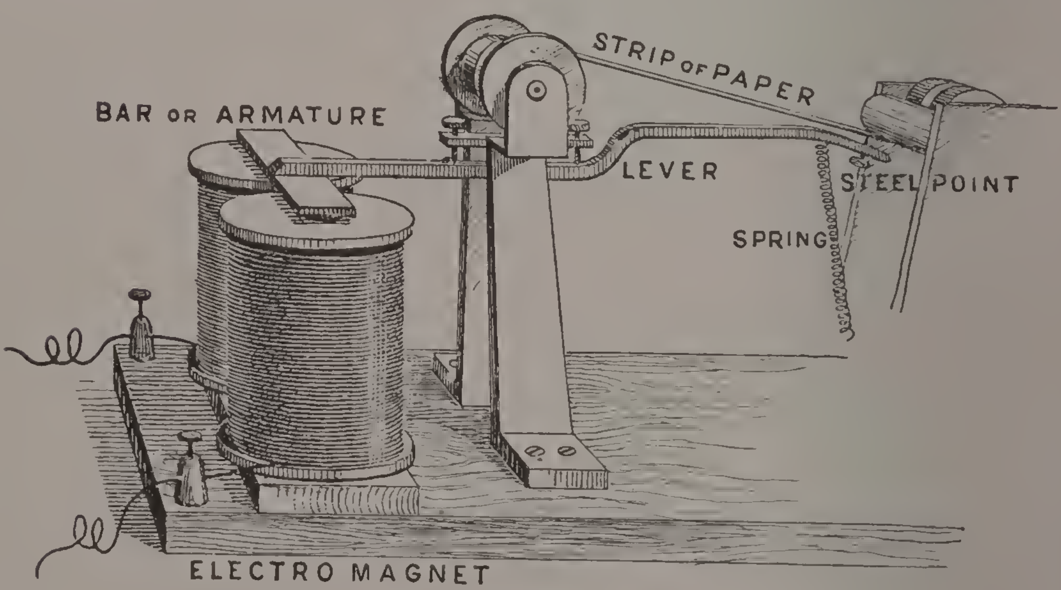
Single cell and battery—several cells joined.

piece of soft iron, and the iron was at once made a magnet. It drew the iron filings as the bar magnet did. As soon as he separated the wires, the iron filings fell off. The iron had lost its magnetism.

He tried steel instead of iron; it was magnetized like the iron, but when the current was broken, it did not lose its magnetism as the iron had done.

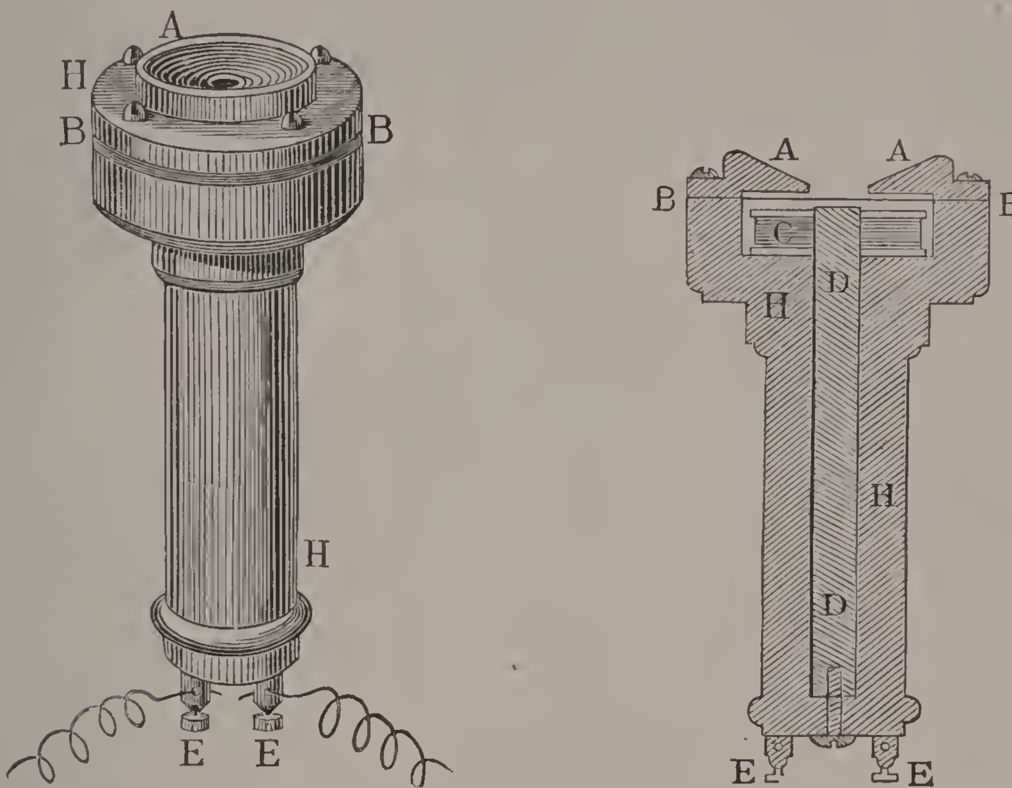
Galvanic electricity is used for telegraphy (*tele*, far, and *graphy*, writing). The cells used hold about a gallon; a copper plate is put in the bottom and the zinc is suspended above it in the liquid, which is water having in it blue crystals of copper sulphate. Many such cells are connected and form one large battery in the large offices. The wires and the earth make the circuit through which the current flows. When the operator puts down his key the circuit of the current is complete, and the keys in all the offices in the circuit are drawn down with a click.

If you look at this telegraph instrument you will see two spools of wire carefully wound with silk. In the center of the coils is a core of soft iron. When the current passes through the wire, the core is mag-



Self-recording telegraphic instrument.

netized and draws the bar or armature above down on itself and the click is heard. As soon as the operator lifts the key the circuit is broken, the core loses its force and the bar is raised by a spring.



The telephone—entire and sectional views. *D D* is a steel magnet; *C*, a coil of copper wire wrapped with silk, its ends connected with binding screws, *E E*; *B B* is a thin disk of soft iron tightly clamped around its edge to the two parts of the wooden case *H H*, which are held together by screws, while the central part of the disk is left free and nearly touches the magnet *D D*; *A A* is the mouthpiece through which the speaker directs his voice upon the iron disk, making it vibrate against the magnet.

The telephone (*tele*, far, and *phone*, sounder) works on the same principle. In telegraphing the operator presses down the key and thus closes the circuit; but in the telephone there is a very thin plate that takes the place of the armature, and this is pressed against the core by the sound vibrations. Every vibration completes the circuit, and the current magnetizing the core at the other end of the line makes its plate vibrate just as the plate at the speaker's end does, and thus reproduces the same sounds with all their qualities. These and a number of other inventions depend on the fact that soft iron is instantly magnetized by a current and as quickly demagnetized when the current is broken. It is a simple thing, and it is a wonder to me that it was not discovered and applied long before it was.

THE END.

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